The London School of Economics and Political Science

Impacts of Better Transport Accessibility: Evidence from Chile

Kenzo Asahi

Thesis submitted to the Department of Social Policy of the London School of Economics for the degree of Doctor of Philosophy

London, June 2015

Declaration

I certify that the thesis I have presented for examination for the MPhil/PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others.

I declare that my thesis consists of 54,389 words.

Abstract

The anatomy of disadvantage in Chile and in Santiago is a product of a long history and is broad and deep, with great income inequality and widely dispersed populations. These conditions are also not unusual in other middle-income countries and fast growing economies, many of which are also investing heavily in urban transport systems at this time.

In the mid-2000s, in an effort to confront some of these problems, there was a large expansion of Santiago's (Chile) subway network (Chapter 2). This thesis investigates the socioeconomic impacts of the much-improved urban transport accessibility.

This expansion occurred within a short period of time (2004 through 2006). Because of a conjunction of efforts by the Chilean government to evaluate the effectiveness of the country's social policies, there is much data available characterising the socioeconomic conditions both before and after the expansion. For example, in this thesis I use a panel survey with circa 5000 interviewees with labour market outcomes, administrative panel data with standardised test scores of 100,000 students in eighth grade, and police crime records with all reported crimes to the police in Santiago.

To control for workers (Chapter 4), students (Chapter 5) and small crime areas (Chapter 6) individual and unobserved characteristics that do not change in time, I use a fixed-effects method. Depending on the outcome, the unit of observation was an individual or a spatial unit. In addition, to allow for differential pre-existing trends in the outcome variable, in the first-differenced form I control for relevant baseline characteristics.

There are three socioeconomic conditions examined in detail in this thesis. These are impacts on the labour market (in Chapter 4), student achievement (in Chapter 5), and property crime (in Chapter 6).

In Chapter 4, my general findings are that greater proximity to the subway network increases labour market participation, employment hours, and labour earnings. However, the main policy implication of this part of the study is that accessibility of transportation is a crucial factor affecting the female employment rate. This is extremely important in cities with a low female employment rate and a low or non-existent coverage of rapid transit systems such as subways.

In Chapter 5, I find that increased proximity to the subway network is associated with substantially lower test scores. Policy implications to consider are that schools that will soon be more accessible to rapid transit systems should consider the possibility of undesired increases in class sizes due to more demand because of the increased availability of nearby rapid transit stations.

In Chapter 6, I find that greater proximity to subway stations increased both robbery and larceny in the public space within one year after the opening of the subway stations. One policy implication is that the police should redistribute its personnel whenever the flows of pedestrians and commuters may be affected because of changes in the transport network.

In light of the well-established fact that citizens appreciate improvements in the subway network that increase their accessibility to employment and to services in general, this thesis provides evidence that a relevant advantage of better urban transport is an improvement in labour market conditions.

Acknowledgements

I would like to thank my supervisors for their generosity, support, and advice. Stephen Jenkins has taught me to have the big picture always in mind and—through his example—he has shown me the importance of professionalism in every aspect of academic life. Steve Gibbons has taught me the value of analysing every question through the lenses of economic analysis. Both have helped me to think and justify each word I write in my manuscripts.

I have used administrative and survey data from different sources. I am grateful to every person who responded Chile's CASEN panel survey, to every student who took Chile's SIMCE test and to every police officer who recorded crimes in Santiago in the mid-2000s. I am also grateful to the researchers and surveyors who have designed, gathered, and disseminated these datasets. Special thanks go to my funders: the Department of Social Policy at the LSE, the Santander Travel Fund, and an anonymous donor.

I would like to thank all those who have provided insights and suggestions on my work. In particular to Rodrigo Wagner, Shawn Chen, Ben Wilson, Felipe Severino, Olmo Silva, and Milo Vandemoortele. I am especially grateful to the insightful comments of Virginia Hathaway.

I am grateful to the community in CASE for day-to-day friendly atmosphere and access to interesting seminars. In particular, I have greatly enjoyed relaxing at lunchtime (and even having cream tea!) with Rikki Dean, Kerris Cooper, Elena Mariani, Polina Obolenskaya, and Jack Cunliffe. I am grateful to Joe Joannes and Jane Dickson for their help in CASE.

This thesis would have not been possible without the help from my son Keitaro's carers. I am deeply grateful to Marcia Violani, my mother-in-law Susana, my sister-in-law Pachi and the teachers at MACE Montessori.

I am especially grateful to my parents. This PhD is the culmination of a long academic history, which started when they enrolled me in a British school decades ago. I thank their generosity in investing so much time, love and resources on our education.

I am deeply thankful to my family. I will never forget the face and voice of my two-year-old son Keitaro when, on random occasions during the last stages of this PhD, he has asked me 'Papá, have you finished your book?' During these three years in the program, I have greatly enjoyed hundreds of lunches, conversations, suggestions, and shared the emotional roller coaster of the thesis' vicissitudes with my beloved wife Marigen. I dedicate this thesis to them and our future children.

Table of Contents

List of Tables

List of Figures

Glossary of Terms

Accessibility: '[E]xtent to which individuals and households can access day to day services, such as employment, education, healthcare, food stores and town centres' (Department for Transport 2011).

Domestic burglary: Unauthorised entry into the dwelling of the victim with the intention of stealing something. In this thesis, I use 'burglary' as shorthand for 'domestic burglary'.

Domestic violence in the dwelling ('domestic violence'): Wounding, assaults, or psychological violence that involves household members.

Human capital: 'Loosely speaking, human capital corresponds to any stock of knowledge or characteristics the worker has (either innate or acquired) that contributes to his or her "productivity"' (Acemoglu and Autor 2009, 3).

Larceny in the public space ('larceny'): Stealing something of value without the use of force or intimidation. This category includes snatch theft, where the use of force is just enough to snatch the property away and stealth theft, where the victim is unaware of the larceny.

Property crime: In this thesis, property crimes include burglary, robbery, and larcenies.

Rapid transit: High-capacity public transport that operates on an exclusive right-of-way, typically rail tracks.

Robbery in the public space ('robbery'): taking or attempting to take something of value by force or intimidation.

Santiago: Unless explicitly noted, in this thesis, 'Santiago' refers to the Santiago Metropolitan Region (one of the fifteen administrative regions in Chile, as well as the country's capital).

Socioeconomic: '[R]elating or concerned with the interaction of social and economic factors' (Oxford University Press 2014). More specifically, in this thesis, these social and economic factors include labour market, academic achievement, and property crime.

Subsidised housing: Housing that receives a subsidy from the Government to provide affordable housing to low-income households through tenure.

Subway: Underground rapid transit system.

Value added in education: 'Value added is a measure of the progress students make between different stages of education.' (Department for Education 2014)

Violence in the public space: Wounding and assaults in the public space.

Violent crime: In this thesis, violent crimes include domestic violence and violence in the public space.

Chapter 1

Does Public Transport Play a Role in a City's Socioeconomic Outcomes?

Does transport play a significant role in the socioeconomic success of cities? In the words of Edward Glaeser, 'cities are the absence of physical space between people and companies. They are proximity, density, closeness… Their success depends on the demand for physical connection' (2011, 6). The goal of this thesis is to explore the impact of increased physical connections and accessibility through better urban transport on socioeconomic outcomes in Santiago de Chile's Metropolitan Region ('Santiago').

The key event in this impact analysis is the dramatic extension of Santiago's transportation system in the mid-2000s. This extension happened in the context of great disadvantage and inequality in Santiago, and a remarkable lack of transportation adequately serving the poor. Because of this expansion, more than 50 per cent of households in Santiago increased their proximity to the subway network. A very high percentage of these households were in the vast sections of the city inhabited by the poor.

Both in the mid-2000s and currently, Chile and its capital Santiago had extremely high rates of inequality in income, labour market, academic achievement and crime across socioeconomic groups. Citizens in the poorest income deciles groups had a low share of income, a high perception of increased crime, and lower employment rates and educational performance relative to citizens in the poorest income deciles groups in other Latin American and OECD countries. This socioeconomic inequality has its urban counterpart in a high spatial segregation in Chile's capital. Compared to citizens in wealthier neighbourhoods, citizens in poorer neighbourhoods in Santiago had worse accessibility to employment, lower employment rates, worked fewer hours, earned less, and attended schools of lower grades.

The socioeconomic outcomes I will look at are labour market, student achievement, and property crime outcomes. Labour market outcomes—especially labour earnings—are crucial for a households' economic status. Academic achievement is a crucial determinant of individuals' future labour earnings (Neal and Johnson 1996). Hence, I consider student achievement as another dimension of an individual's socioeconomic outcomes. In addition, because property crime—although illegal and unproductive at the aggregate level—is a form of employment (Becker 1968), I also consider the level of property crime as a socioeconomic outcome. I examine the effect of urban transport accessibility on all these socioeconomic outcomes because these are crucial dimensions in citizens' well-being, and there is previous evidence—detailed in the next paragraphs—that the effect of better urban transport accessibility on these outcomes may be significant.

This topic is timely and important because middle-income countries and fast growing economies like China, Brazil, and Russia are investing heavily in their urban transport systems—especially in rapid transit systems (Gaubatz 1999, Ferreira and Alves 2012, Moscow City Government 2014). Despite this large investment, the literature with well identified parameters about the impacts of better urban transport accessibility on socioeconomic outcomes in developing countries is relatively thin. For example, Chen and Whalley (2012) concluded that the inauguration of the Taipei subway in 1993 implied a sharp decrease in carbon monoxide, but almost no change in level ozone pollution. Although environmental characteristics are not necessarily socioeconomic outcomes, both dimensions are related through individuals' well-being. An assessment of these impacts in a middle-income country could help inform policy makers in several middle-income countries and fast growing economies around the world about socioeconomic impacts when they are making investment decisions about urban transport infrastructure.

Why might improved transport access at workers' place of residence change labour market outcomes? Gibbons and Machin (2006) argue that transport may affect labour market outcomes through three channels: labour supply, labour demand, and the equilibrium between labour supply and labour demand. Regarding labour supply, better accessibility, by definition, lowers the cost of commuting to most employment destinations in a city. Hence, an improvement in the transport network may increase the number of people willing to work by decreasing their reservation wage. In a standard labour market model, a reduction in the reservation wage (the lowest wage at which a worker is willing to be employed) would shift the labour supply curve rightwards, increasing the employment rate and lowering wages. As I argue in Chapter 2, given the spatial mismatch between the residence of low-income workers in the metropolitan edge and jobs in the centre-business district, in Santiago's case the labour supply channel may be a relevant one. Regarding labour demand, better transport accessibility may affect firms' behaviour with respect to their location, their demand for labour, and wages (the latter, in cases of firms with some monopsonistic power) (Gibbons and Machin 2006). Regarding the equilibrium between labour supply and demand, better transport accessibility may improve the matching process between workers and firms. This can be the result of increased effort and distance to feasible commuting locations due to reduced commuting costs (Phillips 2012).

Hence, an expansion of a city's transport infrastructure may decrease frictions in the labour market (Coulson, Laing, and Wang 2001). This may enhance the benefits of agglomeration economies on workers' labour market outcomes (D'Costa et al. 2013).

Student achievement may be affected by better urban transport accessibility because of changes in the value added provided by the students' school or by direct effects on students not mediated by the school. Several potential mechanisms operate through schools. Increased urban transport accessibility may lead to an upturn in school enrolment. Because of the importance of class size to outcomes, if this leads to greater class sizes, better urban transport accessibility may actually decrease student performance. Krueger and Whitmore (2001) find that a decrease in class sizes from 22–25 students to 13–17 students in the Tennessee STAR project improved test scores taken twelve years after the beginning of the intervention by 13 per cent of a standard deviation. In a related research using teacher/student ratios as a key variable, Banerjee et al. (2007) find in data from India, that having an additional teacher in a class improved test scores by 10 per cent of a standard deviation one year after the program was over.

In addition to the mechanism of class size, better transport accessibility could affect the value added provided by schools through school competition. In an educational market with free school choice, schools that are more accessible face more competition from other schools. Card, Dooley, and Payne (2010) find a positive effect of competition on test scores (6–8 per cent of a standard deviation). On the other hand, Gibbons et al. (2008) find modest effects for faith-based voucher schools. In another study, Gibbons and Telhaj (2011) found that increased pupil mobility modestly reduces student test scores due to school disruption.

There are a number of other potential mechanisms that are not mediated by schools. Better urban transport accessibility may affect student performance through changes in neighbourhood characteristics. However, Gibbons et al. (2013) find no effect of changes in socioeconomic characteristics of neighbourhoods on students' test scores. On the other hand, increased transport accessibility increases the students' access to attractive destinations of truancy. Although the research on the destinations of truancy is extremely thin, anecdotal evidence (The Branding Brothers 2008) shows that most destinations of truancy in Santiago such as parks and movie theatres are in places served by the subway network. Hence, greater proximity to the subway network may increase truancy and this may reduce student achievement. Alternatively, greater proximity between the student's school and the subway network may imply a reduction in travel time to school for affected students. If this reduction in commuting time results in an increase in study time or in the effort at school because the students are not tired from travelling, better school accessibility could improve student achievement.

Property crime is the third socioeconomic factor I will consider that might be affected by greater access to public transportation. Better urban transport accessibility may affect property crime rates through three mechanisms. First, better urban transport accessibility implies better access to jobs for the potential perpetrators (see Chapter 4). This, in turn, could decrease the number of property crimes committed by the affected individuals. Following the seminal contribution to the field of the economics of crime by Gary Becker (1968), rational choice theories state that every individual evaluates the benefits and costs of legal and illegal work and chooses the option that maximises the expected utility. In an example of evidence in favour of using a rational choice perspective to model property crime, Machin and Meghir (2004) conclude that there is a strong negative association among low-paid workers between wages and property crime.

An implication of a rational choice perspective to model the occurrence of property crime is that the latter decreases when access to legal jobs increases. This is because the opportunity cost of crime also increases. Using USA data, Wang and Minor (2002) found that there is less crime in areas with good job accessibility. However, they use data aggregated at the census tract level and do not control for unobservable variables that could be correlated with both job accessibility and crime rates (for example, individuals with less skills for the legal job market may choose to live in locations with worse accessibility to the legal labour market). Ihlanfeldt (2002) investigated the differences in the association between job accessibility and crime rates in black and white neighbourhoods in the USA. He concluded that if black neighbourhoods were to have the access to jobs (defined as a product between the employment rates and the distance from jobs) enjoyed by white neighbourhoods, the difference between property crime rates in black and white neighbourhoods would be 21 per cent lower. Ihlanfeldt does not exploit exogenous changes in job accessibility. Hence, the changes in job accessibility he exploits could be associated with other (unobserved) characteristics of census tracts that could be driving the crime rates such as local economic shocks.

A second mechanism through which urban transport accessibility may affect property crime rates is by decreasing the journey-to-crime for potential perpetrators, thus increasing the crime rate near the improved transport infrastructure (Brantingham and Brantingham 1981). Using data from Indianapolis, White (1931) finds that crime was concentrated in the central business district, with some individuals commuting to commit crime. An essential aspect of understanding criminal mobility is understanding the urban system as a 'crime opportunity structure' (Capone and Nichols 1976, 200). From a rational choice perspective, all else being equal, a criminal would prefer to commit an offense which required shorter rather than longer trips (Brantingham and Brantingham 1984). As a third mechanism, better urban transport access due to new subway stations might increase the number of commuters who are attractive targets around these new stations. Because theory predicts an ambiguous effect of better urban transport accessibility on property crime rates, the effect of an expansion of the subway network on property crime rates is an empirical question.

In this thesis, I derive causal estimates of the impact of better urban transport accessibility on socioeconomic outcomes. To derive causal estimates, I adopt the 'experimentalist' approach. The experimentalist approach 'emphasises the distinction between variables that have causal effects, control variables, and outcome variables' (Angrist and Krueger 1999, 1278). Hence, in this thesis, by carefully selecting my treatment and control groups in each of the empirical chapters (Chapters 4, 5, and 6), I put 'issues of identification and causality at centre stage' (Gibbons and Overman 2012, 188). To obtain this thesis' causal estimates, I use changes in proximity to the nearest subway station induced by a large expansion of the subway network in Santiago in the mid-2000s. I argue that, conditional on some baseline characteristics, this expansion is an exogenous shock to the proximity to the subway network. My identification strategy uses panel data before and after the subway expansion to derive a fixed-effects estimator that accounts for endogeneity in the relation between the distance to the subway network and the socioeconomic outcomes of the affected individuals and areas.

The first contribution of this thesis is its use of a careful fixed-effects identification strategy and exploit an expansion of a subway network to assess the impact of closer proximity to the subway network on socioeconomic outcomes. By controlling for baseline characteristics of individuals in the chapter on labour market outcomes (Chapter 4), of students in the chapter on student achievement outcomes (Chapter 5), and baseline characteristics of neighbourhoods in the chapter on crime outcomes (Chapter 6), my estimates are robust to differential trends in the dependent variable for individuals, students and neighbourhoods with differing baseline characteristics. In Chapters 4, 5, and 6, by carrying out falsification checks to test my identifying assumptions, I show that there is no evidence that my identifying assumption in each chapter do not hold.

The second contribution of this thesis is an assessment of the impact of better urban transport accessibility on socioeconomic outcomes in the context of a middle-income country. To my knowledge, the few studies that have explored such impact have been conducted in the USA and the UK. Given the differences in labour market institutions, institutional contexts, performance in education, and levels of and trends in crime, the results obtained in the UK and the USA are not necessarily applicable to a middle-income country like Chile.

This thesis is structured as follows. Chapter 0 sets the scene by presenting trends in economic outcomes, income and spatial inequality, employment, schooling, and crime outcomes in Chile and Santiago. Santiago's pattern of disadvantage is closely related to Chile's urbanisation process over the last 150 years. The rapid population growth experienced by the city in the mid-20th century is associated to the fact that the city was not able to absorb adequately the demands of the most vulnerable population in terms of access to employment, transport, housing and schooling. Santiago's high income, labour market, academic achievement and crime perception inequality is also reflected in spatial inequality across all these dimensions. In the early 2000s, citizens in subsidised housing on Santiago's metropolitan periphery had to commute long hours to get to the central business district were most employments was located, had a lower employment rate and, controlling for parental socioeconomic characteristics, exhibited a lower academic performance relative to citizens in wealthier neighbourhoods in Santiago.

In Chapter 3, I explain the methods I use in Chapters 4, 5 and 6 to estimate impacts of better transport accessibility on socioeconomic outcomes. Chapter 3 also discusses my definition of transport accessibility.

Chapter 4 uses household panel data to estimate the impact of better transport accessibility on labour market outcomes. There is clear evidence that, controlling for worker's unobserved characteristics such as ability, greater proximity to the subway network increases earnings, employment, and hours of work. A substantial increase in the female employment rate accounts for the rise in employment rate. A placebo experiment in the period when there was no subway expansion (1996–2001) provides evidence that there are no pre-existing trends in the employment rate biasing my results. This chapter provides evidence suggesting that urban public transport is a key factor of labour market outcomes in cities.

Chapter 5 uses panel data from an administrative source to estimate the impact of better school accessibility on student performance. I find that closer proximity to the subway network is associated with lower test scores. I also find suggestive evidence that this association is at least in part due to an increase in the number of students in schools that experienced a large decrease in distance from the subway network. My results are not due to selection caused by higher dropout of the worst students in the group, who experienced a large increase in proximity to the subway network. I also show that the statistical significance of my results is robust to spatial correlation between the regression errors.

Chapter 6 uses administrative data about all the crimes reported to the police before and after the subway expansion in Santiago in the mid-2000s to estimate the impact of better transport accessibility on property crime. Closer proximity to the subway network implies a substantial increase in reported robbery and larceny. There is no evidence that this association is due to an unobserved citywide shock (such as the increase in mobile phones between 2005 and 2007) that could have driven the effect. In addition, there is no evidence that this association is due to an increase in the rate of reported crimes to total crimes in the areas that experienced an increase in proximity to the subway network. Hence, Chapter 6 does not provide evidence that one of the drivers of the positive valuation of closer proximity to the subway network could be a reduction in property crime.

Chapter 7 concludes the thesis by summarising its contributions, discussing policy implications, suggesting venues of potential future research and pointing out the type of data that would improve the robustness of this thesis' conclusions. The analysis in this thesis could be improved by the use of instruments that could satisfy the exclusion restriction by only affecting socioeconomic outcomes through the transport improvement. I further explain some of these potential instruments in Chapter 7. While each chapter has a section that summarises and presents some implications of the findings, Chapter 7 develops those conclusions further and integrates the conclusions across chapters. Better urban transport accessibility improves labour market outcomes (employment rate, labour earnings, and hours worked). However, better urban transport accessibility implies lower student achievement and an increase in robbery and burglary. The main policy implication is that urban public transport accessibility is a crucial factor affecting the female employment rate. This is extremely important in cities with a low female employment rate and low or inexistent coverage of rapid transit systems such as subways. Other policy implications that I consider are that schools that will experience a future increase in proximity to rapid transit systems should plan accordingly to avoid undesired increases in class sizes due to more demand after nearby rapid transit stations are inaugurated.

Chapter 2

An Anatomy of Disadvantage in Chile and Santiago

There is a long history of urbanisation in Chile and its capital Santiago, a process that has been developing over the last 150 years, and has resulted in the increasing primacy of the Santiago metropolitan region in its share of the country's population. By the early 2000s (the baseline period in Chapters 4, 5, and 6) and currently, Chile and Santiago had extremely high rates of inequality in income, employment, schooling and crime across socioeconomic groups. Citizens in the poorest income deciles groups had a low share of income, a high perception of crime increase, and lower employment rates and educational performance relative to citizens in the poorest income deciles groups in other Latin American and OECD countries. This socioeconomic inequality has its urban counterpart in a high spatial segregation in Chile's capital. Compared to citizens in wealthier neighbourhoods, citizens in poorer neighbourhoods in Santiago had worse accessibility to employment, lower employment rates, worked fewer hours, earned less, and (conditional on their families' socioeconomic status) attended schools whose students, on average, attained lower high school grades.

The topic of this chapter is to what extent the association between urban transport accessibility and socioeconomic outcomes in Chile is generalisable to other contexts. To inform this discussion, I will provide a snapshot of how socioeconomic inequality in Chile has evolved. The chapter focuses on particular aspects of inequality (employment, schooling, and crime outcomes) which were chosen because of their crucial importance to individuals' well-being. These aspects of inequality are discussed in the context of Santiago's history, geography, government policies, and transport patterns.

In addition, the resulting picture of the anatomy of disadvantage in Chile and Santiago will help us understand the socioeconomic impacts of the major expansion of Santiago's public transport infrastructure that occurred in the early 2000s. These impacts are the subject of empirical analyses in Chapters 4, 5 and 6.

The remainder of this chapter is organised as follows: Section 2.1 outlines the history and geography of disadvantage in Santiago. This section serves as background. Section 2.2 details the transport system in Santiago and its major expansion beginning in 2001; Section 2.3 discusses long-term trends in socioeconomic outcomes in Chile and Santiago; and Section 2.4

outlines indicators of disadvantage as of the 2001 transport expansion. Section 2.5 summarises my findings and presents concluding remarks.

2.1 The geography of disadvantage in Santiago

2.1.1 Urbanisation and economic segregation

Santiago's population grew steadily at an annual average rate of 2.7 per cent during the 16th century and the beginning of the 17th century. During the rest of the 17th, 18th, and 19th centuries, the population grew at an average annual rate of two per cent.

However, during the 20th century, Santiago experienced a demographic explosion. This was due to a mining crisis in Chile's north during the 1930s and the migration of rural sectors in the 1940s and 1960s. This, plus high fertility rates, implied that the average annual growth rate of the city's population between 1952 and 1960 was 4.9 per cent. (At the beginning of the 21st century, the average annual growth rate of Santiago's population decreased to 1.4 per cent (COPESA 2010).) In the 1990s, Latin America was the most urbanised developing region in the world and Chile, one of the most urbanised countries in Latin America (Browder, Bohland, and Scarpaci 1995).

Since the 19th century, following the trend of most Latin American nations, Chile's population has become more urbanised and concentrated in its capital. Fig 2.1 shows that, while Chile's urban population increased from 22 per cent in 1865 to 87 per cent in 2002, the proportion of Chile's population residing in Santiago increased from 6 per cent in 1865 to 36 per cent in 2002. Yet, the increasing trend in the concentration of Chile's population in Santiago stabilised during the 1990s. More specifically, the proportion of Chile's population residing in Santiago remained constant in the decade between 1992 and 2002 (35.5 and 35.7 per cent respectively). In fact, 'there were more departures than arrivals to metropolitan Santiago in the … 1997–2002 [period]" (Portes and Roberts 2005, 54).

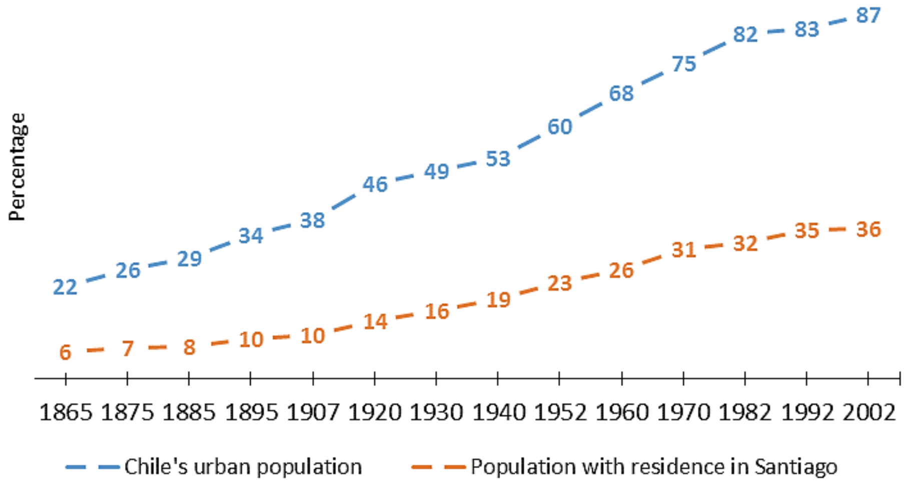


Fig. 2.1 Chile's urban population and proportion residing in Santiago. Note: Author's estimates are from Madaleno and Gurovich's (2004) data.

2.1.2 Santiago's history, geography, urban expansion and housing policy

Santiago has occupied the Mapocho riverside since at least the time of the Spanish conquest, and maybe even as far back as the time of the Incas. From the 16th century until the 19th century, Santiago's population was concentrated in what today is the west of Santiago's central business district (see Fig. 2.2). At the end of 19th century, looking for more space away from the city centre, families of higher socioeconomic status started to migrate towards the east of the city, founding the municipality of Providencia in 1891. The eastern periphery of the city near the Mapocho river is more humid relative to the other very dry areas of the city's periphery (De Ramón 1992; Recabarren 2008; Palmer 2014).

Fig. 2.2 Satellite view of Santiago's geography in 2014. Notes: Santiago's population lives in the grey areas. The mountains are in brown colours. Cultivable land is green. Major roads are in orange. Source: Google Maps (2014).

The area covered by the city also increased. In 1915 Santiago covered 3,007 hectares; this increased to 6,500 hectares in 1930, to 20,900 hectares in 1960, and to 40,619 hectares in the early 1990s (De Ramón 1992). Hence, the annual growth rate of the city's area between 1960 and 1990 was 2.2 per cent.

Fig 2.2 shows that Santiago is in a valley surrounded by mountains. The city's expansion is limited by the Andes range to the east and north and by a series of lower mountains to its west. Since the 1940s, the growth of Santiago has incorporated satellite towns into its metropolitan area in the north, southwest, and south of the city. During the 20th century, the city's most affluent families continued expanding towards the east. However, given the geographical limits imposed by the surrounding mountains, the natural direction for the city's sprawl is to the south (Browder, Bohland, and Scarpaci 1995).

At the same time, during the 20th century, several slums—created through illegal acquisition of land by low-income households—appeared in Santiago. Pinochet's coup d'état in 1973 in Chile ended with illegal acquisition of land in Santiago. During his military dictatorship and the subsequent democratic governments since 1989, the Chilean government carried out an aggressive policy of eradicating slums from Santiago's city centre and the affluent areas in the city's northeast (municipalities of Las Condes and Vitacura) (Hidalgo-Dattwyler 2004).

Unlike in many countries where the government provides public housing through rentals, the Chilean government's strategy was to provide housing through ownership. This was first done in Chile in 1977 when the Chilean government decided to provide low-income families below a poverty cut-off but with a certain amount of savings with a voucher for purchasing housing (Gilbert 2004). This public housing policy had such a significant effect on Chile's housing market that, between 1976 and 2007, 67 per cent of dwellings built were publicly subsidised. In 2002, the proportion of households in Chile who owned their own dwellings was 76 per cent. This was eight percentage points higher than the average proportion of households owning their own dwelling in OECD countries (Simian 2010). Santiago was no exception within Chile in terms of the percentage of subsidised housing out of total housing units.

Given the lower cost of land in the city's periphery, the relocation of the eradicated families in conjunction with the provision of housing through tenure, gave way to publicly subsidised housing projects on the periphery of the metropolitan area. In 2005, according to Brain, Sabatini and Iacobelli (2005), 71 per cent of subsidised housing was at a distance greater than 10 km from the centre of the city. Fig. 2.2 depicts the high concentration of subsidised housing in Santiago's periphery.

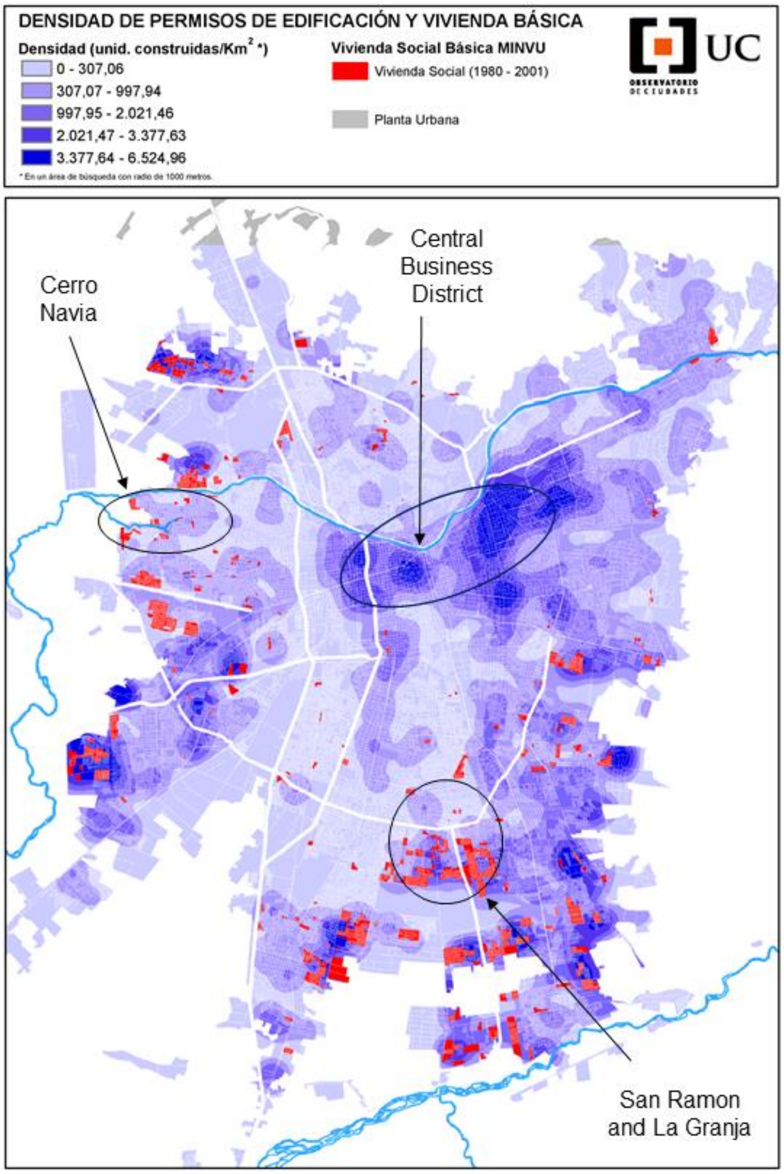


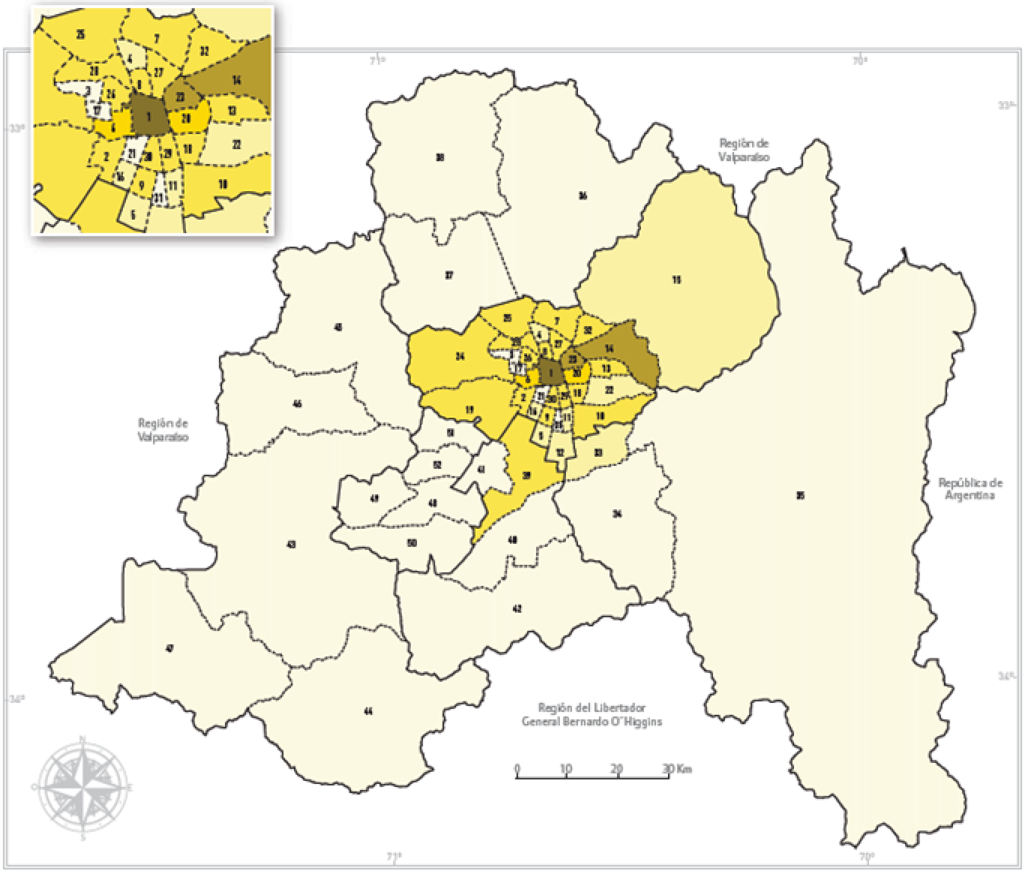
Fig. 2.3 Publicly subsidised housing in Santiago and density of constructions in Santiago (number of dwellings per square kilometre) 1980–2001. Notes: Subsidised housing is in red (darker if printed in greys) and density of constructions is in blue (darker meaning more dwellings per square kilometre). Source: *Observatorio de Ciudades Universidad Católica de Chile* (2011).

When compared to most Latin American capitals, Santiago is a highly spatially segregated city in terms of economic groups. Arriagada and Simioni (2001) find that economic segregation—measured by the Duncan Index of dissimilarity in the ratio of household poverty between municipalities—increased in Santiago between 1992 and 1998.[1] Santiago's economic spatial segregation according to the Duncan Index in the 2001 study was high even when compared to

[1] Although the Duncan index was proposed by Duncan and Duncan (1955) to measure racial segregation, nowadays this index is widely used to measure the economic segregation in terms of the distribution of poor and non-poor households across spatial units in a city. For an example, see Massey and Eggers (1990).

other Latin American cities with high economic segregation such as Lima or Mexico City (Rodríguez and Arriagada 2004).

In 2002, most jobs in Santiago were located near the city's central business district and its northeast. Fig. 2.4 shows the distribution of commuters' destination municipalities in Santiago. This figure shows that the destination of more than 50% of all commuters in Greater Santiago was in the municipalities of Santiago, Providencia Ñuñoa and Las Condes. According to Brain et al. (2005), in 2004, on average, subsidised housing dweller workers commuted 1 hour and 42 minutes round trip per day. Moreover, in La Pintana, a borough in the south of Santiago with the largest proportion of poor households in Santiago and with no subway coverage, in 2010, 48 per cent of workers commuted more than two hours per day to get to their jobs and back. In contrast, in all the wealthiest boroughs in Santiago (Las Condes, Ñuñoa, Providencia, and Vitacura) less than 10 per cent of workers commuted more than two hours per day (El Mercurio 2012).



Number	Municipality	People who commute from another municipality	Number	Municipality	People who commute from another municipality
1	**Santiago**	**434,040**	33	Puente Alto	17,909
2	Cerrillos	25,355	34	Pirque	3,019
3	Cerro Navia	5,911	35	San José de Maipo	915
4	Conchalí	11,877	36	Colina	7,592
5	El Bosque	12,909	37	Lampa	8,268
6	Estación Central	62,193	38	Tiltil	1,643
7	Huechuraba	22,419	39	San Bernardo	29,549
8	Independencia	41,064	40	Buin	7,670
9	La Cisterna	25,827	41	Calera de Tango	2,678
10	La Florida	39,259	42	Paine	2,510
11	La Granja	10,242	43	Melipilla	3,032
12	La Pintana	11,819	44	Alhué	94
13	La Reina	25,246	45	Curacaví	833
14	**Las Condes**	**150,136**	46	María Pinto	300
15	Lo Barnechea	16,688	47	San Pedro	367
16	Lo Espejo	10,184	48	Talagante	6,886
17	Lo Prado	4,940	49	El Monte	1,137
18	Macul	39,128	50	Isla de Maipo	1,461
19	Maipú	37,237	51	Padre Hurtado	3,866
20	Ñuñoa	78,107	52	Peñaflor	3,619
21	Pedro Aguirre Cerda	9,730	Total amount of daily commuters		1,685,798
22	Peñalolén	15,809			
23	**Providencia**	**198,778**			
24	Pudahuel	26,306			
25	Quilicura	39,298			
26	Quinta Normal	30,123			
27	Recoleta	40,404			
28	Renca	22,681			
29	San Joaquín	34,821			
30	San Miguel	44,064			
31	San Ramón	9,303			
32	Vitacura	46,552			

Number of people

	1	-	9.999
	10.000	-	19.999
	20.000	-	49.999
	50.000	-	99.999
	100.000	-	199.999
	200.000	-	450.000

Fig. 2.4 Daily commuters due to work or study according to destination municipality in 2002. Source: Gobierno Regional Metropolitano (2009).

In Alonso's (1964) monocentric city model, there is a trade-off between housing and commuting costs. In equilibrium, this trade-off interacts with the households' wealth, their preferences for dwelling plot size and accessibility to the city centre. Hence, in this equilibrium, the employed reside near the city centre and the unemployed, at the city edge (Zenou 2000). The difference between Alonso's traditional monocentric model and the case of Santiago is that, because the only possibility for affordable housing for low-income households is subsidised housing located on the metropolitan periphery, these households' locations are exogenously determined by the city planner. As Glaeser et al. (2008) point out, in US cities, the poor tend to live in the city centre. They argue that the main factor for why the poor live in the city centre is because they rely on public transport to access employment opportunities. However, the poor in Santiago are assigned by the Government to live on the outskirts of the city and because the poor cannot afford to travel by car to employment opportunities in the city centre, adequate service by public transportation became a major issue. Public transportation and its major expansion beginning in 2001 will be discussed in detail in Section 2.2.

2.1.3 Population and density

In 2001 (before the subway expansion shown in Section 2.2), Santiago's population was distributed unevenly across the city. Fig 2.4 shows the density and population of municipalities in urban Santiago. The municipalities with the highest population densities were in the city's south (La Granja and San Ramón), southwest (Pedro Aguirre Cerda and Lo Espejo) and west (Lo Prado and Cerro Navia). The municipalities of La Granja, San Ramón and Cerro Navia are precisely the ones highlighted in Fig. 2.4 with a high concentration of subsidised housing. Fig. 2.4 also shows that, in 2001, the Santiago subway system did not serve these three municipalities. Hence, Fig. 2.3 and Fig. 2.4 suggest that the Chilean government has been an active actor in the location of vulnerable households and thus in shaping the anatomy of disadvantage in Santiago. It took advantage of cheaper land costs in the west and south metropolitan peripheries where it provided subsidised housing and thus increased the density in that area despite the fact that the area had poor access to a rapid transit system.

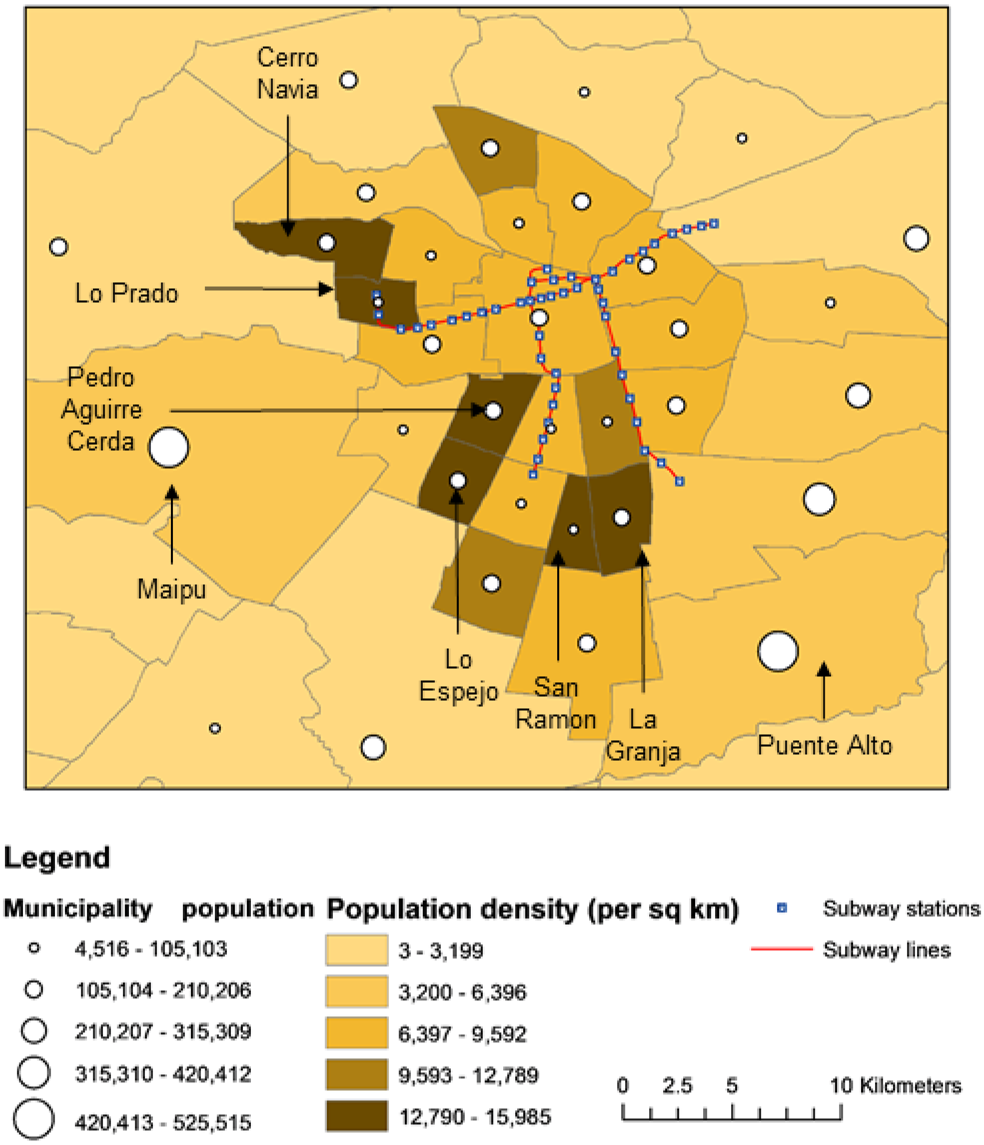


Fig. 2.5 Population, population density of municipalities, and subway network in Santiago in 2001 (before the expansion of the subway network in the mid-2000s). Note: Author's estimates are from the *Instituto Nacional de Estadísticas de Chile* (2014) data.

Having shown Chile's urbanisation process, the concentration of the country's population in metropolitan Santiago, the geographic and historical reasons for a concentration of economic disadvantage in the south and east of the city, and the unusually high proportion of home owners who have benefitted from publicly subsidised dwellings, the next section will discuss the city's overall transport network and the expansion of the subway network in the mid 2000's.

2.1.4 The transport system in Santiago and its major expansion in the mid-2000s

In the early 2000's, the period before the expansion of Santiago's subway network, the transport network was crucial for most Santiago citizens' daily activities. In 2001, there were 13.1 million trips taken in Santiago, 71 per cent of which were motorised (the rest of the trips were made on foot) (SECTRA 2002). Of the motorised trips, 46 per cent of the trips were made by bus, 41 per cent by car, 12 per cent by subway, and 11 per cent in taxi or shared taxi (author's estimates based on SECTRA 2002 data).

Therefore, the two main modes in Santiago's public transport system in the early 2000s were bus and subway. The subway network covered the densest part of the city in terms of population, and was a fast and reliable transport system. A master plan dating from 1968 had established the construction of five subway lines in Santiago (Pávez Reyes 2007). The first three lines (Lines 1, 2, and 5) were inaugurated between 1975 and 1997 and encompassed a 40.2-km railway network (Agostini and Palmucci 2008). Fig. 2.5 shows a map of Santiago's subway network in 2001 (panel A) with lines 1, 2, and 5. Panel B shows Santiago's subway network in the city centre. Lines 1, 2, and 5 are in red, yellow and green. Fig 2.5 shows that Santiago's subway network in the early 2000s did not serve the population in the metropolitan periphery. This was especially true for Santiago's population in the city's southeast, an area that would be served in the mid-2000s by the blue line (Line 4) in panel B. The population in the city's southwest would be served in the early 2010s by the extension of the green line (Line 5).

As with any rapid transit system, Santiago's subway system was fast because it was not subject to congestion. In addition, Santiago's subway had predictable wait times (with timetables being adhered to), and was a safe means of transport.

Panel A: Subway network in 2001. Source: Metro de Santiago (2014)

Panel B: Subway network in 2012. Source: Google Maps.

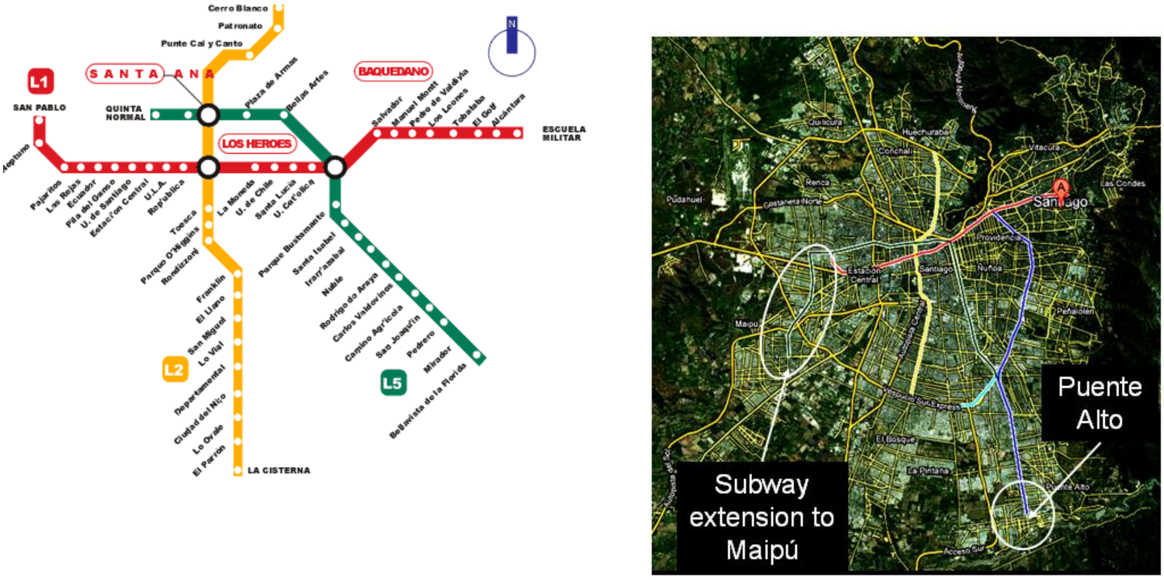


Fig. 2.6 Santiago's subway network

By 2001, the bus network covered the whole city of Santiago including its metropolitan periphery, and had a high share of the city's trips on public transport. Pinochet's military dictatorship (1973–1989) implemented a bus system that had no barriers of entry to new operators. During the 1990s, the newly elected democratic governments of Chile's centre-left Concertación, put out to tender the routes that crossed the city centre. By the late 1990s, there were almost 4,000 bus operators, most of which owned just one bus (Gschwender 2005).

However, the bus network was subject to several problems. It was slow during peak-times, had unpredictable waiting times, and was a dangerous and relatively unpleasant means of transport (Gschwender 2005). First, at peak times, buses were subject to high levels of congestion. This is a characteristic shared by any transport system without exclusive lanes. Second, waiting times were unpredictable. Although the individual operators associated to form bus lines, because of the atomised structure of ownership, buses competed even within the same lines. This competition implied that, 'it was normal to see two or even three buses from the same line travelling together, 'fighting' to catch passengers in the next stop' (Gschwender 2005, 5). Hence, this competition increased bus bunching, making waiting times unpredictable. Third, there was a high probability of accidents involving buses. This was because of the incentives for drivers to go above the speed limits because of the competition between buses, and the fact that drivers often worked long hours because labour laws were not enforced. (see the explanation of 'the war for the fare' by Johnson, Reiley and Muñoz 2005). Fourth, buses in Santiago deteriorated rapidly because of a lack of preventive maintenance. The atomised structure of ownership along the same routes implied a lack of professional management or preventive maintenance schemes for buses (Gschwender 2005). On the other hand, one positive aspect of Santiago's bus system was that the routes were extremely long, so most commuters did not need to make transfers (Gschwender 2005). Hence, in the early 2000s, though it was limited in geographic coverage, the subway network had superior attributes relative to the bus network in terms of speed, safety, and quality of service.

At the beginning of 2001, there were two competing projects to extend Santiago's subway network. One alternative was to extend the subway network to Maipú (in Santiago's southwest); the other alternative, was to extend it to Puente Alto (in Santiago's southeast) (Radio Cooperativa 2001). Each of these two municipalities in the city's metropolitan periphery had a large population (around 500,000) not served by the subway network. (See further below Fig. 2.13 for a map with the location of Maipú and Santiago.)

In May 2001, the Chilean government announced the construction of subway Line 4, a 24-km subway line running from Providencia, located 5 km east of Santiago's central business district, to Puente Alto (see Fig. 2.6). In December 2001, the exact locations of the stations were announced. The new subway line was inaugurated in two phases; the first in November 2005 and the second in March 2006. Before this date, many citizens living in Santiago's most unserviced areas in the southeast of the city (Puente Alto) had more than four-hour round trip commutes each day to get to jobs and schools in the central business district and the wealthier part of the city (Providencia and Las Condes) located in the north eastern part of the city. In addition to this large expansion of the system, between September 2004 and November 2005 Line 2, which runs in the north-south direction, also experienced a (small) extension of the line and the addition of six new subway stations.

The opening of the subway Line 4 to Puente Alto and the extension of Line 2 took place between September 2004 and March 2006. This was the greatest expansion of Santiago's subway network since the 1970s and implied an increase in urban transport accessibility whose socioeconomic impacts I will evaluate in Chapters 4, 5, and 6.

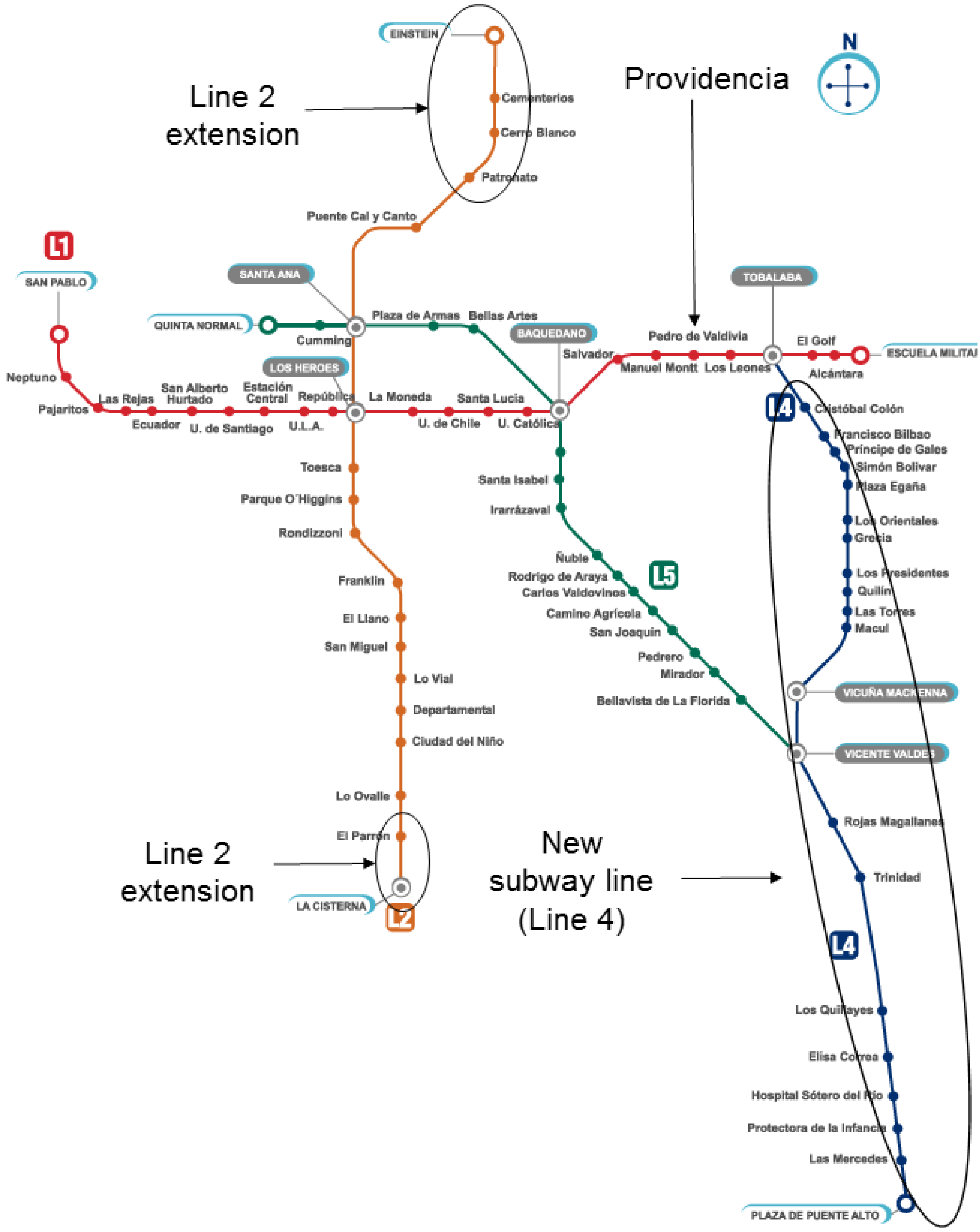


Fig. 2.7 Santiago post-subway expansion (July 2006) subway map. *Note:* Stations inaugurated between September 2004 and March 2006 highlighted with black circles. Source: Metro de Santiago.

In November 2005, Chile's President Lagos announced the 14-km extension of subway Line 5 to Maipú (Atina Chile! 2005) (See this extension in Fig. 2.5 Panel B.). This extension was inaugurated in February 2011. In Chapters 5 and 6, I use the extension of Line 5 to Maipú as a 'placebo experiment' for Santiago's subway expansion in the mid-2000s. One characteristic of this extension that makes it suitable as a placebo experiment is that this was a proposed subway line in the early 2000s that was inaugurated after my post-expansion data (2006 in Chapters 4 and 5 and 2007 in Chapter 6). Another characteristic is that the destination of both proposed subway extensions, the municipalities of Puente Alto and Maipú, share similar characteristics in terms of their location in Santiago's metropolitan periphery and their large population with limited access to Santiago's subway network during the early 2000s. These two facts provided the mayors of Maipú and Puente Alto great bargaining power for lobbying the central government's authorities for the subway to pass through their municipalities.

Having explained the geography of disadvantage in Santiago, in the next section I explain historic trends in socioeconomic conditions in Chile and Santiago.

2.2 Historic trends in socioeconomic conditions in Chile and Santiago

In this section, I document broad socioeconomic trends in Chile and Santiago. Second, this section describes the trends in income, labour market, student achievement, and crime indicators over the last two to three decades (depending on the availability of data) in Chile and Santiago.

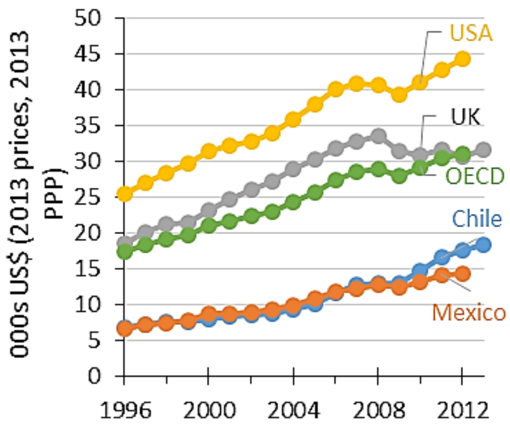
2.2.1 Income and labour market

Chile is a middle-income country that has experienced high economic growth during the last two decades. In 2012, Chile's GDP per capita at purchasing power parity (PPP) was US$17,580. Chile's GDP per capita in 2012 was 43 per cent lower than the average GDP per capita at PPP of OECD countries (OECD 2014b). With a share of 12 per cent in the country's GDP in 2013, and 57 per cent of the country's exports in 2012, Chile's main industry is mining, mainly copper (88 per cent of mining's GDP in 2013) (Banco Central de Chile 2014b). According to the International Monetary Fund (2014), Chile ranked 54 out of 187 countries according to its GDP (PPP) per capita.

To have a better perspective of Chile's economic indicators relative to other countries, I compare Chile's indicators with those of two developed countries (the USA and the UK) and with another middle-income, Latin American country of similar GDP per capita, Mexico. Panel A in Fig. 2.8 shows that Chile's income per capita is below that of the USA, the UK and the average in OECD countries. Since the 1990s, Chile has experienced sustained high economic growth of six per cent of average growth per year.

Santiago has 40 per cent of Chile's population. While Chile's population in 2012 was 17.4 million, Santiago's population in the same year was 7.0 million (Instituto Nacional de Estadisticas 2005). Santiago's income per capita is higher than the average income per capita in Chile. According to the Banco Central de Chile (2014a), in 2012, Santiago's PPP GDP per capita was US$24,783, 10.4 per cent higher than Chile's PPP GDP per capita (see panel B in Fig. 2.8). In 2013, Santiago's GDP was 49 per cent of the country's GDP. The main sector in Santiago's economy is financial and business services (36 per cent), followed by retail, restaurants and hotels (16 per cent), personal services (13 per cent), and manufacturing (11 per cent of Santiago's GDP).

Panel A: Chile's national income per head. Notes: author's estimates are from OECD (2014a) and the Socio-Economic Database for Latin America and the Caribbean (2014a) data.



Panel B: Santiago and Chile's national income per head in 2012. Notes: author's estimates use GDP and GDP deflators from Banco Central de Chile (2014a), population from Instituto Nacional de Estadisticas de Chile (2014b) and Chile's 2012 PPP conversion factor for GDP from OECD (2014b).

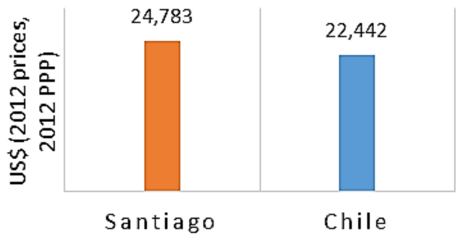
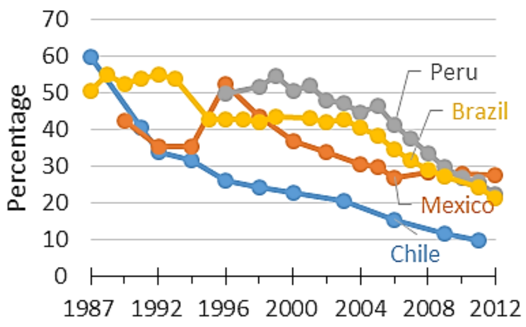


Fig. 2.8 Net national and regional income per head.

Panel A in Fig. 2.9 shows that with an absolute cut-off of US$4/day, Chile's poverty rate using after-taxes and transfers household disposable income fell from 59.9 per cent in 1987 to 9.9 per cent in 2011. In 2011, Chile's $4/day poverty rate was lower than that in Mexico, Brazil, and Peru at 18, 15.9 and 14.6 percentage points, respectively. Most Latin American countries use an absolute cut-off to define their official poverty lines. In Chile, the government's cut-off in 2011 was higher than US$4/day. Instead of 9.9 per cent, its official poverty rate in 2011 was 14.4 per cent. Using Chile's official poverty rate, Santiago's poverty rate in 2011 was 2.9 percentage points lower than the national poverty rate (Ministerio de Desarrollo Social de Chile 2012a).

Panel A: Chile's absolute poverty rate relative to other countries. Notes: The poverty line is set at US$4/day. Author's estimates are from Socio-Economic Database for Latin America and the Caribbean (2014a) data.



Panel B: Chile's relative poverty rate relative to other countries. Notes: The poverty line is set at 50 per cent of contemporary median income. Author's estimates are from OECD (2014b) and Socio-Economic Database for Latin America and the Caribbean (2014a) data.

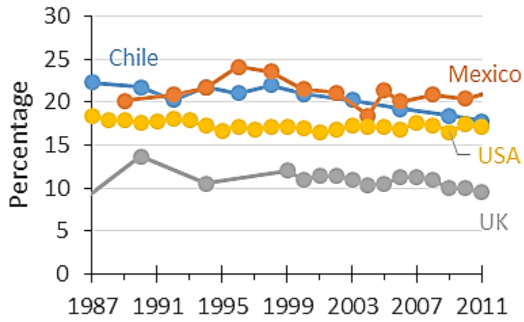
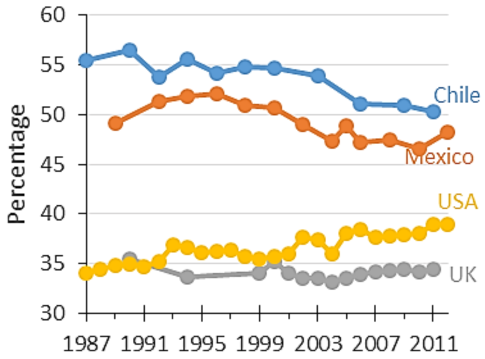


Fig. 2.9 Poverty rate after taxes and transfers. Notes: Equivalised household disposable income.

Similarly, with an after-taxes and transfers relative cut-off of 50 per cent contemporary median household disposable income, Chile's poverty rate has also been decreasing over the past 25 years. Fig. 2.9's panel B shows that while the country's poverty rate of households with incomes below 50 per cent of median income in 1987 was 22.3 per cent, the poverty rate in 2011 was 17.8 per cent. In 2011, Chile's poverty rate was 3.1 percentage points lower than in Mexico, almost the same compared to the poverty rate in the USA and 8.3 percentage points higher than in the UK. Using a relative cut-off, Santiago's poverty rate is similar to the national poverty rate. If the poverty line is set at 50 per cent of the contemporary median income, the poverty rate in Santiago and Chile is 17.4 and 17.6 per cent respectively (author's estimate based on Chile's Casen 2011 data).

Because this chapter deals with disadvantage in Chile, a relevant issue is whether, apart from experiencing reductions in the poverty rate, the country has also experienced reductions in the country's income inequality. Panel A in Fig. 2.9 shows that Chile's income inequality measured by the Gini coefficient decreased from 55.5 per cent in 1987 to 50.3 per cent in 2011. Despite this decrease, in 2009, Chile was within the 12 per cent most unequal countries in the world according to the Gini coefficient (author's calculation based on data from the World Bank 2014). In 2011, Chile's Gini coefficient was 2.9 percentage points higher than Mexico's and much higher than the Gini coefficient of the USA and the UK (11.4 and 15.9 percentage points respectively, see Fig. 2.10's panel A).

Panel A: Chile's income inequality *relative to other countries. Note: Author's estimates are from OECD (2014b) and (2014a) data (see Appendix 1).*



Panel B: Santiago and Chile's income inequality in 2011. Note: Author's estimates are from Casen 2012 data (Ministerio de Desarrollo Social de Chile 2012b).

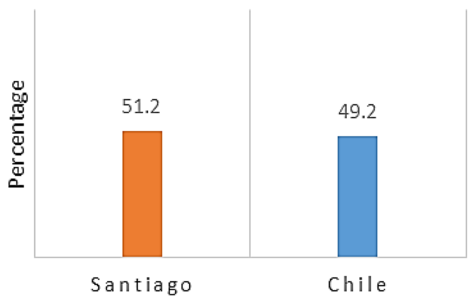
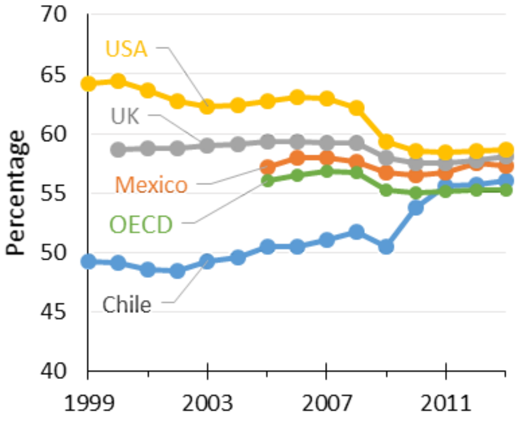


Fig. 2.10 Gini coefficient of income inequality. Notes: Gini coefficient at equivalised household disposable income, post taxes and transfers.

In 2011, Santiago's income inequality as measured by the Gini coefficient was two percentage points higher than Chile's Gini coefficient (see Fig. 2.9's panel B). To have a perspective on what two percentage points in the Gini coefficient means, if Chile's Gini coefficient in 2009 would have been two percentage points higher, Chile would have climbed five places in the ranking of most unequal countries in the World—from place 20 to place 15 out of 158 countries. (Author's calculations based on data from the World Bank 2014.)

Some authors have argued that one of the main structural factors affecting Chile's high income inequality during the 2000s is the high ratio of the employment rate of the richer income groups to the employment rate of the lower income groups relative to the same ratio in other Latin American countries with similar per capita income (Velasco and Huneeus 2012). I now explore the validity of this claim. In 2001, the baseline year in Chapter 4, Chile's employment rate was extremely low. Within 27 OECD countries with available data in 2001, Chile had the seventh lowest employment rate for persons aged 15 and over. Chile's employment rate of 48.6 per cent was far below the OECD average of 55.2 per cent. Panel A in Fig. 2.11 shows that between 2009 and 2013 the employment rate of Chile's population aged 15 and over increased 5.6 percentage points from 50.5 to 56 per cent. This narrowed the employment rate gap with other OECD countries substantially. In 2013, Chile's employment rate was 0.8 percentage points higher than the average in OECD countries and slightly lower than the employment rate in Mexico (another Latin American country with similar income per capita), the UK, and the USA (1.3, 2.1 and 2.6 percentage points respectively) (OECD 2014b).

Panel A: Chile's employment rate relative to other countries. Note: Author's estimates are from OECD (2014a) data.



Panel B: Santiago and Chile's employment rate. Note: Author's estimates are from Encuesta Nacional de Empleo 1986–2009 and Nueva Encuesta Nacional de Empleo 2010–2013 data (Instituto Nacional de Estadísticas de Chile 2014a).

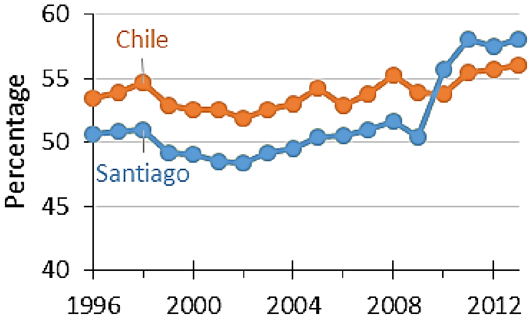


Fig. 2.11 Annual employment rate, aged 15 and over.

Chile's employment rate during the mid-2000s was also low relative to other Latin American countries. In 2003 (this is, before the subway expansion in the mid-2000s), after Honduras and Dominican Republic, Chile had the third lowest employment rate out of 19 countries in Latin America for adults aged 25–64. Chile's employment rate in this age range was 65.4 per cent, several percentage points below the Latin American average (69.9 per cent). Specifically, Chile's female employment rate of 47.2 per cent was the fourth lowest rate within Latin American countries (Socio-Economic Database for Latin America and the Caribbean 2014b).

As can be seen in Fig. 2.11's panel B, in 2001, Santiago's employment rate was four percentage points lower than Chile's employment rate. In terms of country rankings according to their employment rate, a four-percentage point difference is relevant. In 2001, Chile ranked 21 out of 27 OECD countries with available data in terms of its employment rate. Because in 2001 Santiago had an employment rate four percentage points lower relative to Chile's employment rate, Santiago would have ranked 26th out of 27 countries in the OECD.

Chile's low overall employment rate in 2001 was due to an extremely low female employment rate. Out of 27 OECD countries with data for 2001, Chile ranked last in the OECD, with a female employment rate of 31.4 per cent—15.7 percentage points lower than the OECD countries' average female employment rate (see Fig. 2.12). By contrast, the male employment rate in Chile in 2001 was 66.3 per cent. This is 2.3 percentage points higher than the OECD countries' average male employment

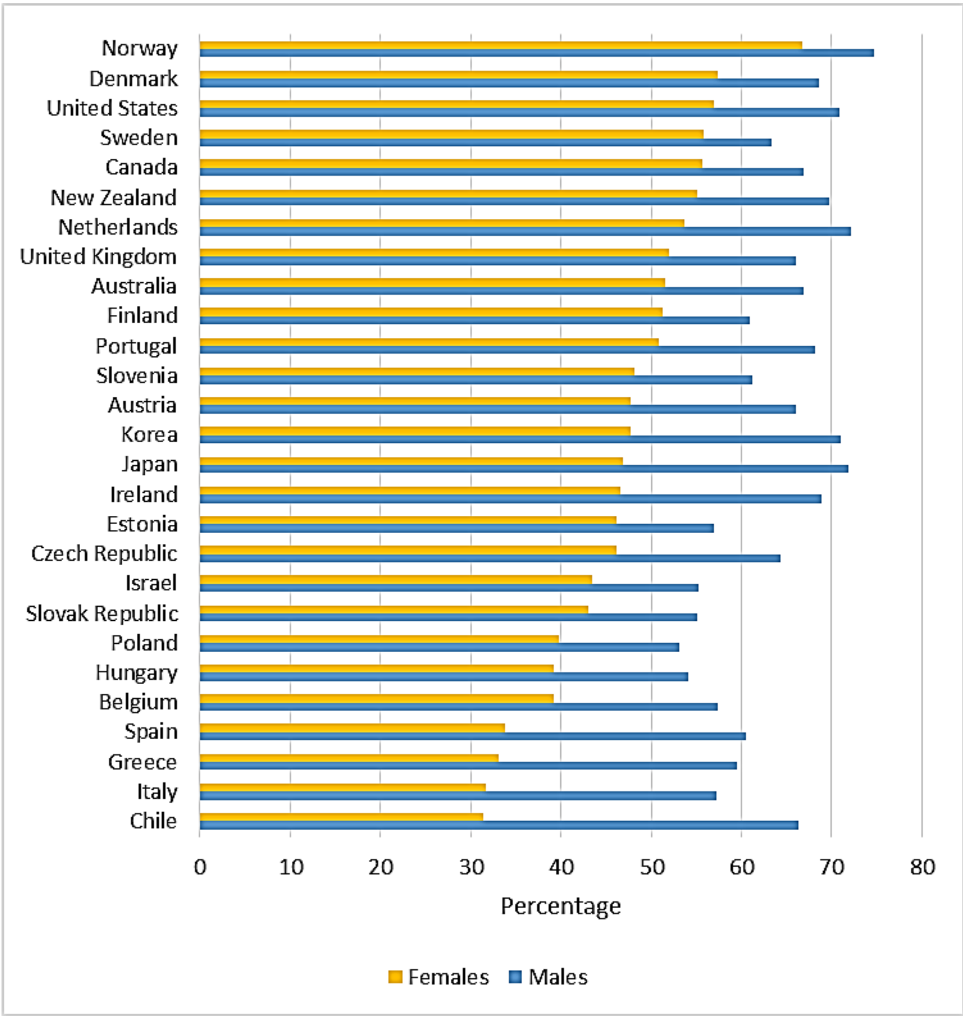


Fig. 2.12 Annual employment rate of OECD countries by sex in 2001, aged 15 and over. Note: Author's estimates are from OECD (2014b) data.

Compared to other middle-income Latin American countries like Brazil, Argentina, Mexico and Uruguay, Chile's employment rate in the three poorest tenths in 2011 was low (Velasco and Huneeus 2012). Fig. 2.12 shows that in 2011 the employment rate of Chile's poorest tenth was 26 per cent. By contrast, this same rate in Brazil, Argentina, Mexico, and Uruguay was 12, 15, 25, and 31 percentage points higher relative to Chile's employment rate in the poorest tenth.

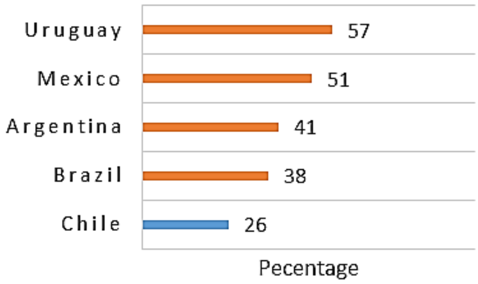


Fig. 2.13 Employment rate of the poorest tenth in Chile and other middle-income Latin American countries. Notes: employment rate is for adults aged 18 to 65 years. Author's estimates are from Velasco and Huneeus' (2012) data.

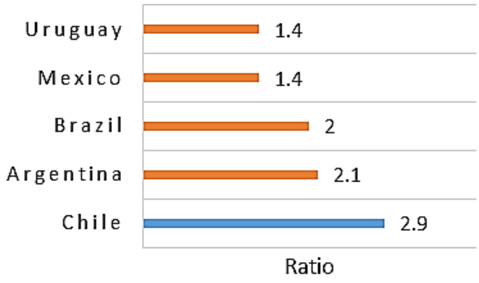


Fig. 2.14 Ratio of the employment rate of the richest tenth to the employment rate of the poorest tenth. Notes: employment rate is for adults aged 18 to 65 years. Author's estimates are from Velasco and Huneeus' (2012) data.

Following Velasco and Huneeus (2012), one way of measuring inequality in access to employment is by using the ratio of the employment rate of the richest tenth to the employment rate of the poorest tenth. According to this measure, Chile's employment inequality is twice as large as in Mexico and Uruguay, and around 50 per cent higher than in Brazil and Argentina (see Fig. 2.13).

Are there any reasons for this high inequality in access to employment? In Section 2.2.2 on the institutional context of schools, I show evidence that Chile's high inequality in access to employment may be due to inequality in human capital acquisition. In addition, Montenegro and Pagés (2004) conclude that 'both minimum wages and job security regulations [during the early 2000s in Chile] reduce[d] the employment opportunities of the young and the unskilled—and particularly unskilled youth—while promoting the employment rates of skilled and older workers' (p. 431). In Section 2.1.2 (on Santiago's urban expansion), I show that affordable housing in Chile is located in the metropolitan periphery without access to rapid transit systems. In that section, I argue that the provision of subsidised housing through tenure to low-income households in the metropolitan periphery is a factor that influences a low employment rate among disadvantaged citizens in Santiago.

Fig. 2.12 and 2.13 provide suggestive evidence that the high inequality in access to employment between richest and poorest tenths may be one of the causes of income inequality in Chile. Why is there a stronger association between household income and employment status in Chile relative to other middle-income countries in Latin America? Given the close association between academic achievement and future wages (Neal and Johnson 1996), in Section 2.2.3 I show data on whether the effect of household income on human capital acquisition in secondary school is higher in Chile relative to other countries. I am interested in student achievement trends in Chile because of the impact of human capital acquisition on economic outcomes (including economic inequality) and in order to provide more context about how economic and educational disadvantage are related to spatial disadvantage in Santiago and Chile. Before showing results in academic achievement, the next section explains the institutional context of schools in Chile.

2.2.2 Institutional context of schools

To have a better understanding of the trends in student performance in Chile, I first explain the schools' institutional setting, which has some unusual characteristics. The Chilean education system is structured as an educational market where schools compete for greater student enrolment. In my sample in the Santiago urban area (the area within 20 km of Santiago's 2006 subway network), there were 1,435 schools in 2004. At that time, 52 per cent (742 schools) were administered by a private institution and received a per-student subsidy from the government ('voucher schools'), 35 per cent (502) of the schools were administered by the local government ('municipal schools'), and 13 per cent (191 schools) were administered by a private institution receiving no subsidy from the government ('private schools').2

Since 1981, the Chilean school system has been structured on five key characteristics. First, the government subsidy for municipal and voucher schools is a per capita sum proportional to student attendance. Second, voucher schools are allowed to select students from the applying pool of students and may charge families an additional top-up fee to families. Third, school entry is a relatively unregulated process with practically no administrative barriers for new schools (Gallego and Hernando 2008). Fourth, families are free to choose any school within their budget constraint (i.e. there were no catchment areas). Despite the non-existence of catchment areas, the median distance between the residences of students in fourth (primary) grade in 2002 and their school was 1.9 km (Gallego and Hernando 2009). Fifth, as a cap on oversubscription, Chilean law mandates that the maximum class size is 45 students. Oversubscribed municipal schools select students using academic criteria, and voucher and private schools use academic and other criteria. For instance, faith-based schools may take into

[2] An additional 1% of schools (28) were run by Associations of companies or private entities that administered vocational schools.

account the family's religious participation, and international (e.g. British) schools may take into account a family's cultural background.

The next section shows the results that Chile's market-oriented and relatively unregulated school system has delivered, and the association between these results and households' socioeconomic status.

2.2.3 Academic achievement in secondary school

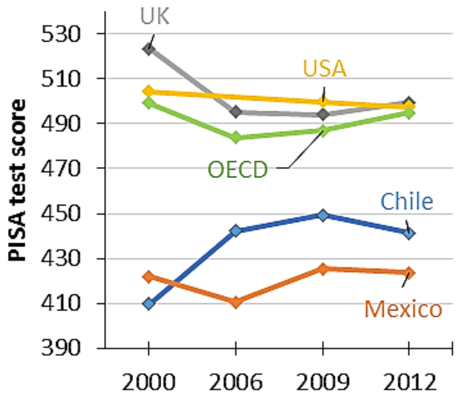
Is the association between income disadvantage and academic disadvantage stronger in Chile than in other countries? Given the positive impact of academic achievement on future labour earnings, a strong relation between household income and student achievement would provide suggestive evidence of a pervasive reinforcing cycle of disadvantage.

Although the performance of secondary school students in Chile was low in 2000, during the last 10 years it has improved substantially. In 2000, Chile's 15-year olds who took the 'Programme for International Student Assessment' (PISA) test in reading ranked 38 out of the 42 countries that took the PISA test[3]. In 2012, Chile climbed five places, ranking 33 out of 42 countries. Because no other country which had ranked in the last 15 places in the PISA 2000 climbed more than two positions by the 2012 ranking in reading , Chile's improvement is remarkable. Panel A in Fig. 2.14 shows that in 2000, Chile scored below Mexico, the OECD, the USA, and the UK in reading—by 12, 90, 95, and 114 points respectively. By contrast, in 2012, Chile scored higher relative to Mexico—18 points higher—and narrowed the gap with the OECD, the USA, and the UK—to a difference of 54, 56, and 58 points respectively. On the other hand, Panel B in Fig. 2.14 shows that in 2000 the average 'Sistema de Medición de la Calidad de la Educación' (SIMCE, System for the assessment of the education quality) test score of students was the same in Santiago and Chile.

---

[3] I exclude Macedonia because students in this country did not take the PISA test in 2012.

Panel A: Chile's PISA test score in reading relative to other countries. Notes: the PISA test is taken by 15-year olds. Author's estimates are from PISA (2014) data.



Panel B: Santiago and Chile's SIMCE test score for 14-year olds (primary grade's 8th grade) in 2013. Note: Author's estimates are from SIMCE 2013 data (Agencia de la Calidad, Ministerio de Educación de Chile 2014).

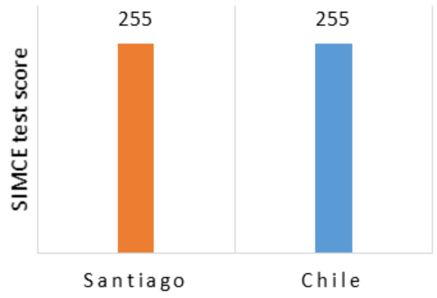
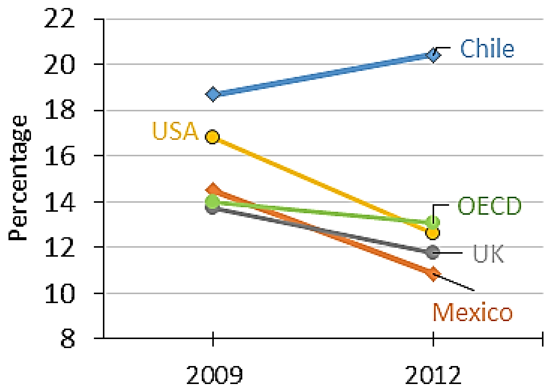


Fig. 2.15 Average test score in reading.

Despite such improvements in reading, the economic, social, and cultural status of Chilean students' families strongly predict the students' test scores in reading and mathematics. According to PISA's economic, social, and cultural status indicator in 2012, Chile ranked fourth and third—out of 63 countries—in terms of the amount of variance in the reading and mathematics PISA test scores respectively.[4] Panel A in Fig. 2.15 shows the explanatory power of the economic, social and cultural status indicator on student's PISA test score for Chile relative to other selected countries. One of the worrying issues is that not only is Chile's performance highly determined by families' socioeconomic and cultural status but also the proportion of the variance of test score explained by the socioeconomic and cultural status increased in the 2009–2012 period. Panel B in Fig. 2.15 shows that, according to the 2004 SIMCE test, the explanatory power of the family's socioeconomic status for Santiago's students is even larger than for Chile's students.

[4] According to PISA (2013), 'The PISA index of economic, social and cultural status was derived from the following three indices: highest occupational status of parents […], highest educational level of parents in years of education according to [the International Standard Classification of Education] ISCED […], and home possessions.' (p. 200). For details on the derivation of the index of home possession and other technicalities, see Appendix 3.

Panel A: Explanatory power of the economic, social and cultural status indicator on students' PISA test score in reading for Chile and other selected countries. Source: author's estimates are from OECD (2013) and OECD (2010) data. Note: The explanatory power is derived using a single-level bivariate regression of performance on the economic, social and cultural status, the slope is the regression coefficient for the economic, social and cultural status.



Panel B: Santiago and Chile's explanatory power of the school's income category on students' SIMCE test score in reading in 8th grade in 2004. Notes: author's estimates are from SIMCE 2004 dataset. The explanatory power is derived using the R-squared in a regression of performance on the student's school income level. The school's income level corresponds to the category of the school's median household. There are 30 categories of school income level.

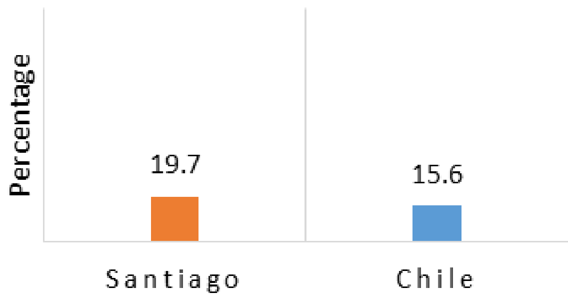


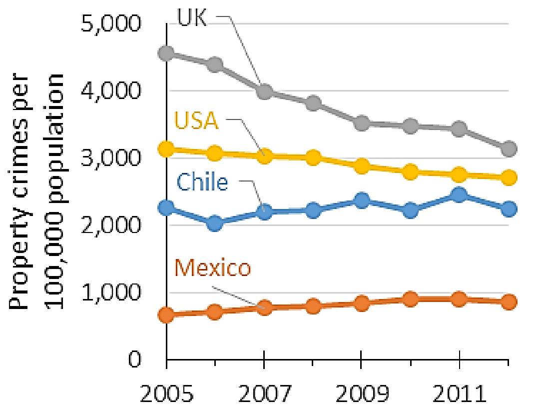
Fig. 2.16 The association between school performance and socioeconomic and cultural status.

Hence, Fig. 2.15 provides evidence that the academic achievement of students in Santiago and Chile is highly determined by their parents' socioeconomic (occupational status, educational level and wealth) and cultural status (cultural possessions, home educational resources, and books). In turn, this is suggestive evidence that, at least from the perspective of human capital acquisition, Chile's income inequality might continue to be extremely high in the future. However, employment and schooling outcomes are not the only determinants of citizens' well-being. Well-being is also determined by neighbourhood characteristics, including crime rates (Ludwig et al. 2012). Hence, in the next section I describe the trends in property crime in Chile and Santiago, and detail how the perception of increases in property crime distributes across socioeconomic groups during the last decade. This also helps to provide a wider picture of disadvantage.

2.2.4 Crime

Between 2005 and 2012, the rate of property crime per 100,000 inhabitants recorded by Chile's police remained stable (see Panel A in Fig. 2.16): in 2005, this rate was 2,258 reported crimes per 100,000 population; in 2012, it was 2,241 reported crimes per 100,000 inhabitants. This provides background information for Chapter 6 on the impact of better transport accessibility on property crime reported to the police. On the other hand, the rate of property crime recorded by the police in the UK and the USA decreased substantially during the same period. In the case of the UK, this figure decreased from 4,574 to 3,133 property crimes recorded by the police per 100,000 inhabitants in 2005 and 2012 respectively.

Panel A: Chile's police-recorded property crime rate relative to other countries. Note: Author's estimates are from the United Nations Office on Drugs and Crime (2014) data.



Panel B: Santiago and Chile's crime rate. Proportion of households with at least one member victim of a crime during the last 12 months. Note: Author's estimates are from the Encuesta Nacional Urbana de Seguridad Ciudadana data (Ministerio del Interior y Seguridad Pública 2014; Ministerio del Interior y Seguridad Pública 2014b).

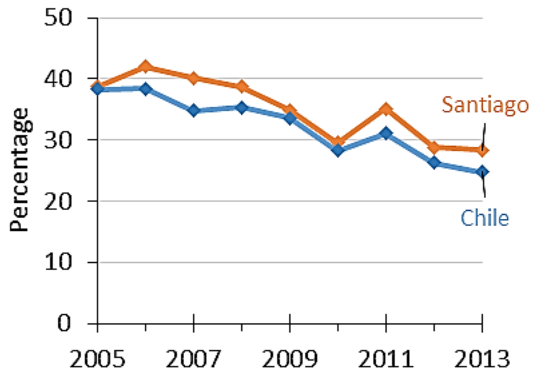


Fig. 2.17 Crime rates.

By contrast, according to Chile's 'National Urban Survey of Public Safety' ('ENUSC' in Spanish), the proportion of households in which at least one member was a victim of crime during the prior year experienced a sharp decrease of 13.5 percentage points, changing from 38.3 per cent in 2005 to 24.8 per cent in 2013 (see panel B in Fig. 2.15). The discrepancy between this information in the ENUSC survey and the police-recorded crime could be because panel A shows the rate of property crime and panel B, the rate of all crimes. In addition, during this period the willingness of Chilean citizens to report crimes could have increased. This possibility motivates the fact that in Chapter 6 on the impact of better urban transport accessibility on property crime rates, I analyse the robustness of my results to changes in victims' willingness to report crime to the police. On the other hand, Panel B in Fig. 2.16 shows that between 2005 and 2013, the proportion of households in which at least one member has been the victim of a crime in Santiago follows a similar trend to the one experienced by the country as a whole.

During the 2000s, there was a dissonance between perceived and reported crime rates by socioeconomic groups in Chile. Panel A in Fig. 2.18 shows that individuals of lower socioeconomic status are more likely to perceive that crime has increased in their neighbourhood during the prior year relative to individuals from higher socioeconomic status. By contrast, Panel B in Fig. 2.18 shows that individuals from all socioeconomic levels have experienced a decrease in the proportion of households with at least one victim of crime during the prior 12 months. Moreover, this proportion is lower for individuals of lower socioeconomic status relative to the same proportion for individuals of higher socioeconomic status.

Panel A: Proportion of individuals who report perception that crime has increased in their neighbourhood during the last 12 months by socioeconomic status.

Panel B: Proportion of households with at least one member who reported being victim of a crime during the last 12 months by socioeconomic status.

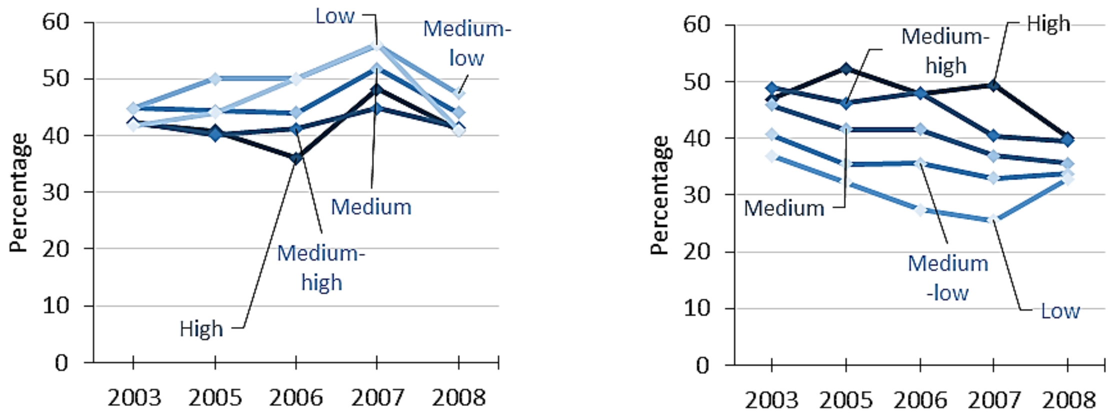


Fig. 2.18 Crime by socioeconomic status in Chile. Note: Author's estimates are from Godoy and Gillmore (2009) based on Chile's Encuesta Nacional Urbana de Seguridad Ciudadana 2003–2008 data.

This section shows that Chile is a middle-income country that has experienced high economic growth and a drastic reduction in poverty, but whose income inequality—particularly in Santiago—has remained high over the last two decades. In addition, this section shows that Chile's employment rate in the early 2000s—especially the female employment rate and that of the lower income decile groups—was extremely low relative to other Latin American countries. All these characteristics also apply to Santiago. I then show that Chile's student achievement was extremely low relative to the achievement results for countries that took the PISA test in 2000. I also show recent evidence that the explanatory power of a student's socioeconomic and cultural statuses on student performance is high in Chile relative to countries in the OECD, and to comparable countries like Mexico. Moreover, the explanatory power of students' economic status on student achievement is even higher in Santiago relative to the same explanatory power in Chile as a whole. Finally, this section shows that individuals of lower socioeconomic status in Chile systematically report a higher perception that crime is increasing relative to individuals of higher socioeconomic status.

2.3 Specific indicators of disadvantage, as of the mid-2000s subway expansion

This section provides a picture of the labour market, academic achievement, and property crime outcomes across the municipalities in Santiago in the early 2000s, the period before Santiago's subway expansion and the baseline period for Chapters 4, 5, and 6.

2.3.1 Labour market

Fig. 2.19 shows that, in 2001, average labour earnings for the population aged 15 and older[5] were higher for individuals living in municipalities in Santiago's northeast (Las Condes and La Reina) relative to individuals living in the city's southwest (especially in Lo Espejo and Cerrillos). This figure shows the average monthly labour earnings of the population aged 15 and over in every municipality surveyed in the Panel Casen survey in 2001. For an explanation for the criteria that determined the inclusion of municipalities in the sample and the list of included municipalities, see Appendix 2. Fig. 2.19 also shows the subway network in 2001 (before the expansion in the mid-2000s).

---

[5] This is, assuming zero earnings from labour for non-working individuals.

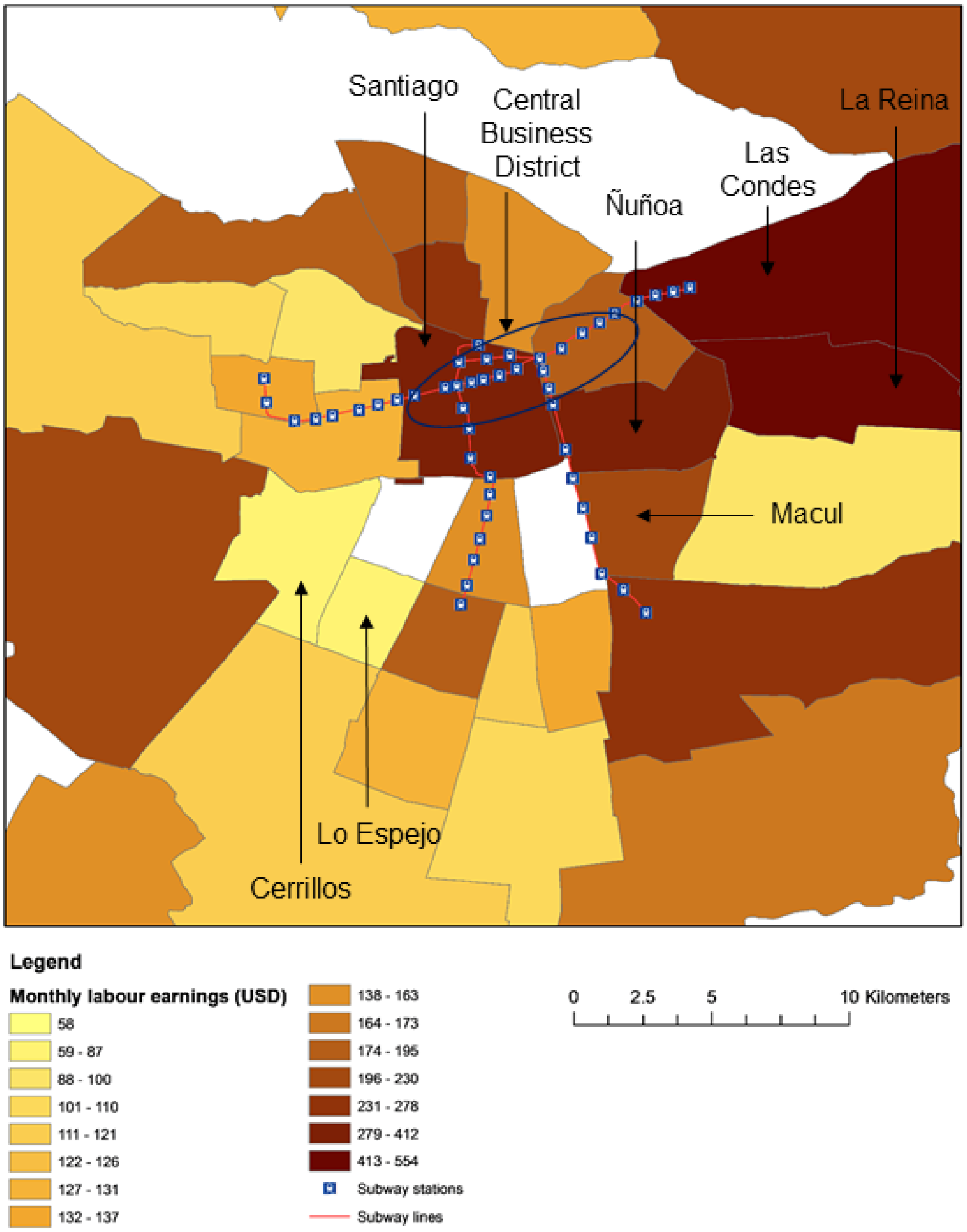


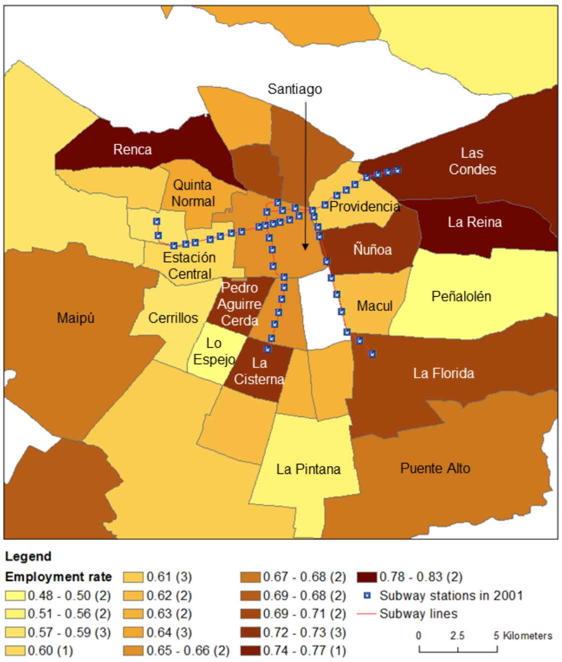
Fig. 2.19 Average monthly individual labour earnings of municipalities in Santiago and the city's subway network in 2001 (before the expansion of the subway network in the mid-2000s). Notes: Author's estimates are from Chile's Panel Casen data. The sample is restricted to population 15 years and older in 2001 who were not full-time students in that year. The Panel Casen survey did not sample municipalities in white (it excluded some municipalities with small population through a lottery). See Appendix 2 for more details.

In Alonso's (1964) monocentric city model, high earners with a preference for good accessibility (as opposed to having large plots of land) choose to live near the central business district, and low earners with a weak attachment to the labour market choose to live on the metropolitan periphery with poor access to the central business district. By contrast, Glaeser et al.'s (2008) observation that the poor tend to live nearer to the central business district because they rely on public transport would imply a negative association between transport accessibility to the centre business district and employment rates. In the case of Chile and in line with Glaeser et al.'s (2008) argument, Sanhueza and Celhay (2011) highlight the fact that, despite the high supply of housing subsidised by the Chilean government, in 2008 Santiago still had slums located relatively near the central business district. According to these authors, living in slums in Santiago is a strategic decision by slum dwellers to improve their access to jobs.

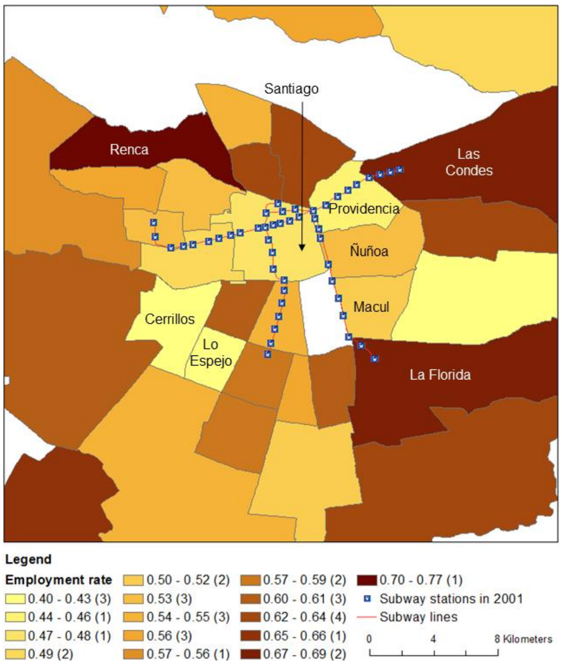
Interestingly, Fig. 2.19 provides visual evidence of a labour earnings and good accessibility to the central business district using the subway network. Hence, this figure provides some suggestive visual evidence in favour of Alonso's monocentric city model.

Fig. 2.20 shows the employment rate of municipalities in Santiago in 2001. In line with the predictions from Alonso's monocentric model and with Fig. 2.19, I expect employment rates to be greater in districts with greater accessibility. Panel A shows the employment rate in 2001 of men and women aged 15 to 59 who were not in full-time study. I constrain the age to 59 because the retirement age of females in Chile is 60 years old. Panel A provides suggestive evidence that other factors apart from accessibility to the central business district affect employment rates. In this panel, there is no clear association between employment rates and accessibility to the central business district. Hence, this panel does not provide visual evidence in favour of the predictions of Alonso's monocentric model.

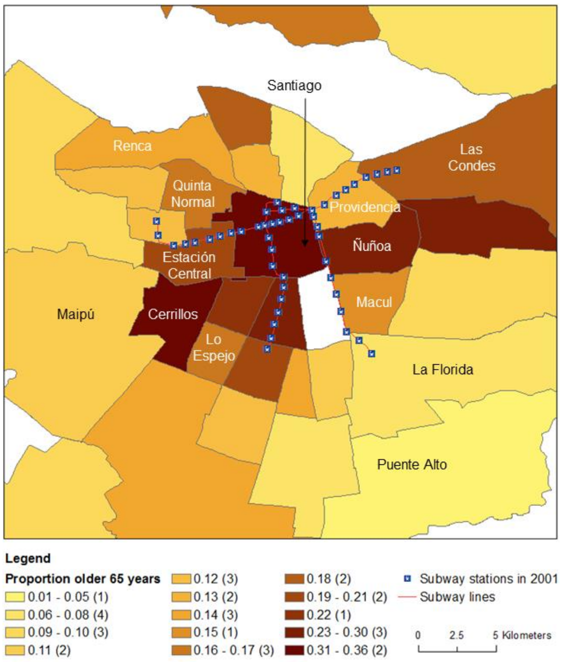
Panel A: Employment rates of men and women aged 15 to 59.



Panel B: Employment rates of men and women aged 15 and older.



Panel C: Proportion of the population aged 65 and older.



Panel D: Employment rates of women aged 15 and older.

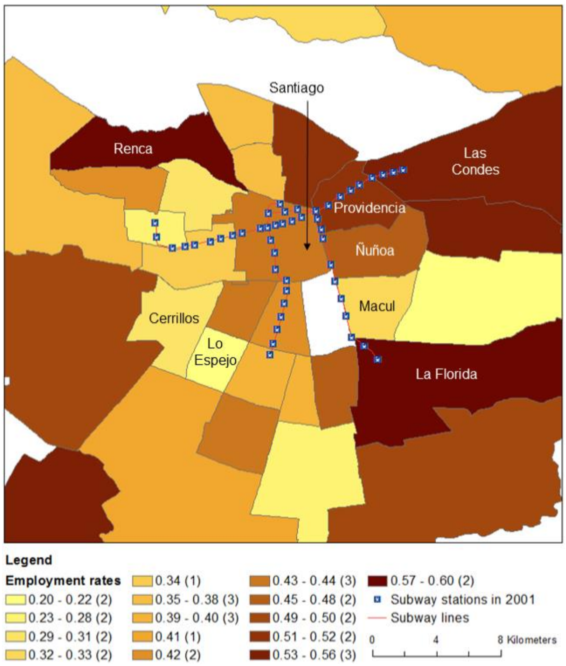


Fig. 2.20 Employment rates for different age ranges and proportion of the population aged 65 and older in municipalities in Santiago and the city's subway network in 2001 (before the expansion of the subway network in the mid-2000s). Notes: Author's estimates are from the 2001 wave of Chile's Panel Casen data. The sample is restricted to population 15 years and older in 2001 who were not full-time students in that same year. The Panel Casen survey did not sample municipalities in white (it excluded some municipalities with small population through a lottery). See Appendix 2 for more details.

In Chapter 4, I analyse the impact of better urban transport accessibility on labour market outcomes. Because part of the impact can be on the labour market outcomes of the population around retirement age, in that chapter, I do not constrain the sample to a maximum age. To provide a clearer picture of the baseline employment rate in Chapter 4, Fig. 2.20 panel B shows the employment rate of females and males aged 15 and older. This panel suggests that the association between transport accessibility to the city's centre and the employment rate is negative. Panel B shows that the municipalities of Santiago and Providencia—where the central business district is located—had relatively low employment rates (46 and 48 per cent respectively). By contrast, the municipalities of Renca and La Florida—that are farther from the central business district, had higher employment rates (77 and 69 per cent respectively). Because the panel B sample includes individuals of retirement age, a potential explanation for the unexpected negative visual association between employment rates and accessibility could be because municipalities with good accessibility to the central business district may have a high proportion of individuals past the retirement age. Panel C shows the proportion of individuals in each municipality older than 65 years old. I choose this threshold because it coincides with the retirement age of men in Chile. Panel C shows a strong visual association between the proportion of individuals aged 65 and older and accessibility to the central business district.

In Section 2.2.1, I show that the female employment rate in Chile in 2001 was extremely low relative to the male employment rate and relative to the female employment rate in other OECD and Latin American countries. Given this unusually low female employment rate, it would be interesting to explore whether the spatial inequality in access to employment in Santiago is different for females relative to the spatial inequality for the whole population. Panel D in Fig. 2.20 shows the municipal average employment rate of females aged 15 and older. By visual inspection, the female employment rate in this age range shows a slightly stronger association with transport accessibility to the central business district relative to the general population's employment rate in the same age range (panel B). For example, panel D shows that the female employment rate in municipalities with good transport accessibility like Providencia and Santiago is higher than the employment rate of the other municipalities in Santiago. Hence, the spatial inequality in employment access for women in Santiago is visually different from the spatial inequality in access to employment for the whole population. This suggests that in Chapter 4 I should analyse whether the impact of better urban transport accessibility is different for women relative to the same impact on men.

Therefore, in 2001 in terms of labour market outcomes, individuals in Santiago's northeast had the highest labour earnings and worked more both in the extensive and in the intensive margin relative to individuals in the rest of the city. By contrast, individuals in the city's southwest had lower average earnings from labour and were less likely to be employed relative to individuals in the rest of the city.

Is there any evidence that could help us forecast how spatial inequalities and disadvantage will evolve? Given the predictive power of human capital on future labour market outcomes, in the next section I explore the distribution of spatial educational performance and opportunities in Santiago.

2.3.2 Academic achievement in secondary school

Fig. 2.21 shows the spatial distribution of student performance in Santiago according to the 2004 SIMCE test score in mathematics. This figure shows that schools in the city's northeast have higher average test scores (on average, higher than 75 per cent of one standard deviation above the national mean). In contrast, schools in the city's west and south exhibit the worst test scores in Santiago (on average, lower than 22 per cent of one standard deviation below the national mean). The map in this figure is consistent with the general picture portrayed by Fig. 2.19, where labour earnings were also higher in Santiago's northeast and lower in the city's west and south.

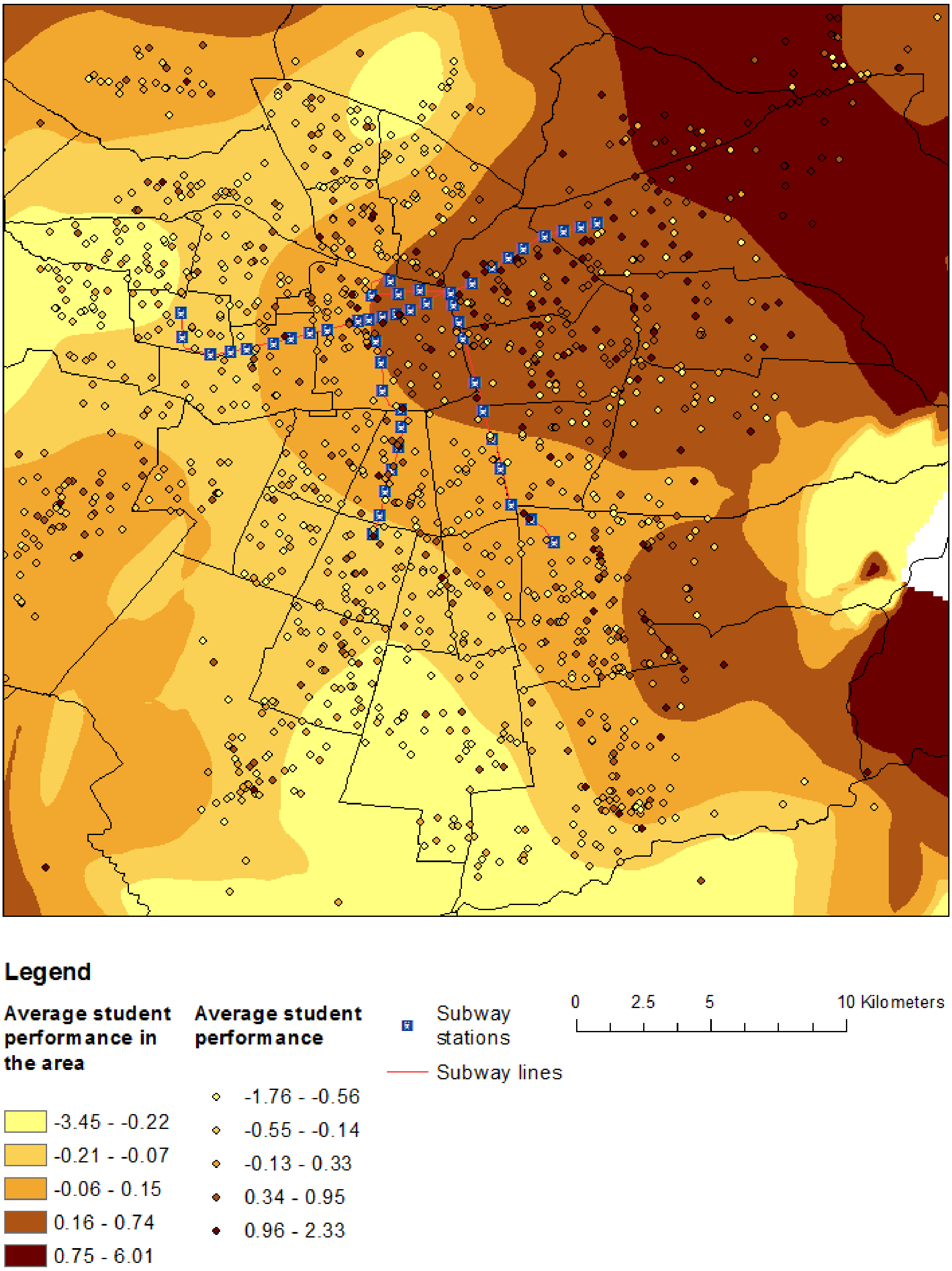


Fig. 2.21 'Average student performance in each school' and 'average student performance in the area' of eighth-graders (13 year olds) in the 2004 SIMCE test in mathematics and Santiago's subway network in 2004 (before the expansion of the subway network in the mid-2000s). Notes: The unit of observation for the average student performance is each school. The average student performance in the area is an interpolation of the average student performance in each school. This is a kernel interpolation with barriers with an Epanechnikov kernel of bandwidth 2.7 km. Test scores are measured as z-scores standardised at the national level with a mean of zero and a standard deviation of one.

Given the close relation between human capital and future wages, educational performance is relevant insofar that it enables us to have an idea of the future map of economic disadvantage in a city. However, evidence about the spatial inequalities of educational opportunities in Santiago would also be relevant. Hence, a Santiago map showing the average value-added to students in each school would be ideal to show this distribution. A crucial input to a school value-added calculation is data for the same student in the same school over two periods. Unfortunately, to my knowledge, there are no panel datasets with test scores in Chile's capital during the early 2000s that would enable me to derive value-added calculations.

An indicator that could provide an imperfect but still valuable proxy for school value-added is what I call 'contextual student performance'. I define average contextual student performance as the average test score in a certain cohort of a school controlling for characteristics of students that affect achievement that are beyond the school's control. These characteristics could include, for example, the student's gender as well as socioeconomic characteristics such as household income and parental level of education. The strength of the contextual student performance indicator is that, because it controls for socioeconomic characteristics as well as the student's gender, the indicator does not reflect the socioeconomic characteristics of the students' families, or the student's gender. The weakness of contextual student performance as a proxy for school value-added is that the individual (unobserved) talent of the student could still dominate my proxy for school value-added. As I explain in Section 2.2.2, one of the characteristics of Chile's educational system during the 2000s is that voucher, private schools, and oversubscribed municipal schools were able to select students for such things as their abilities. This magnifies the possibility that my measure of contextual student performance is influenced not only by the schools' value-added to student achievement, but also by the students' innate ability. To my knowledge, no other researcher has calculated proxies of school (or teacher) value-added using only cross-section data.

Fig. 2.22 shows the average contextual student performance for the different areas in Santiago. I calculate the contextual student performance by running a regression of eighth graders' individual test scores in the 2004 SIMCE test score in mathematics on household income, maternal and paternal levels of education (primary, secondary, vocational, graduate, or postgraduate education) interacted by the number of maternal or paternal completed years of education, the child's gender, and a dummy variable for each school in Santiago.[6]

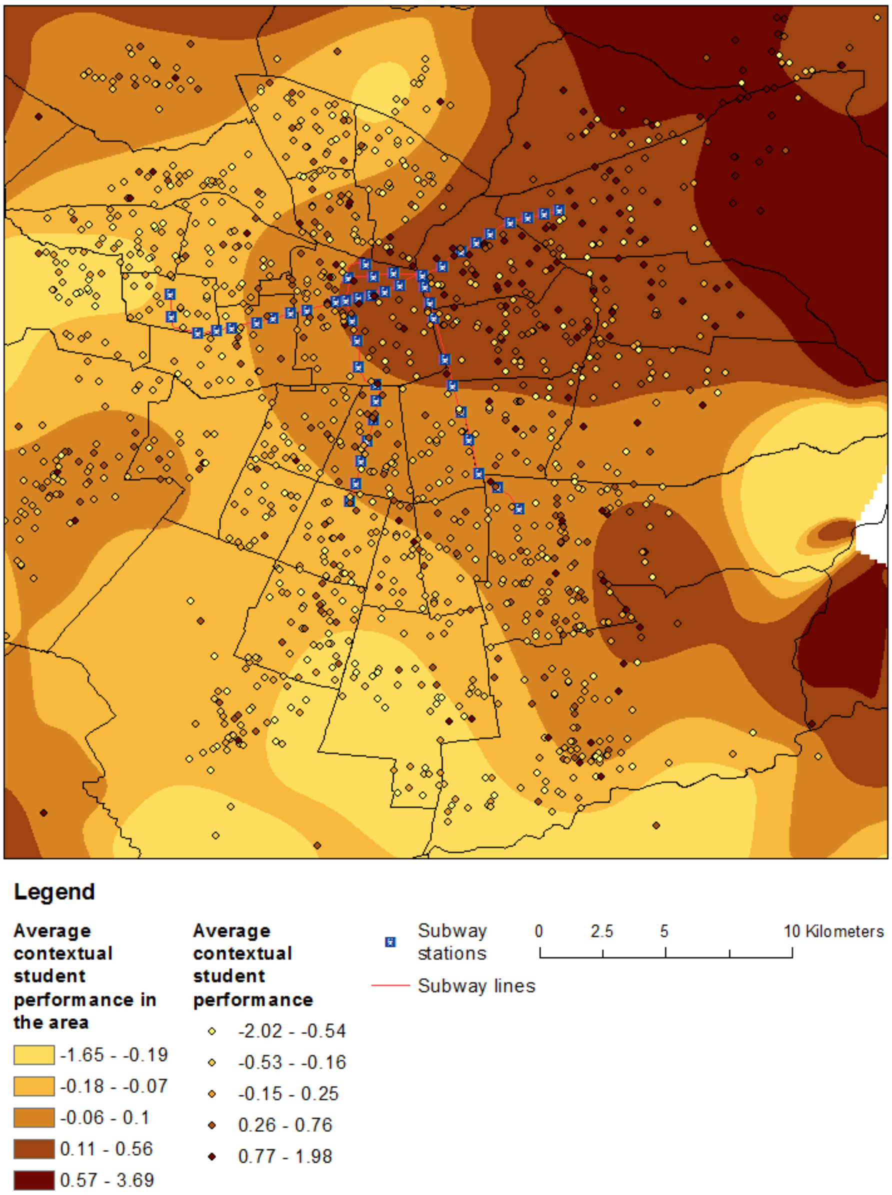


Fig. 2.22 'Contextual average student performance' and 'contextual average student performance in the area' of eighth-graders (13 year olds) in the 2004 SIMCE test in mathematics and Santiago's subway network in 2004 (before the expansion of the subway network in the mid-2000s). Notes: The unit of observation for the contextual average student performance is each school. The contextual average student performance in the area is an interpolation of each school's contextual average student performance. This is a kernel interpolation with barriers with an Epanechnikov kernel of bandwidth 2.7 km. Test scores are measured as z-scores standardised at the national level with a mean of zero and a standard deviation of one.

---

[6] See Appendix 4 for a detailed description of the method of imputation of missing values for each of these socioeconomic variables.

I interpret the coefficient on each school's dummy variable (this is, the school fixed-effects) as the average contextual student performance for each school. When running this regression on these test scores, both the student's gender as well as the maternal and paternal levels of education interacted by the number of parental completed years in the highest education level are highly significant. In addition, the correlation between student performance and contextual student performance is 58 per cent. Hence, the contextual student performance measure is not identical with the student performance measure itself. Despite this non-perfect correlation, Fig. 2.22 shows that the map of contextual student performance is remarkably similar to the one of student performance.

This section provides suggestive evidence that, although student performance and contextual student performance do not correlate entirely, the degree of spatial inequality in average student performance and of educational opportunities in different areas in Santiago go hand in hand. On the other hand, as mentioned in Chapter 1, there is a large body of literature that hypothesises and concludes that an improvement in legal employment opportunities decreases the incentives for illegal employment (or crime). Having reviewed the spatial inequality in employment and schooling opportunities in Santiago, in the next section I explore the spatial inequality in property crime outcomes in Santiago. A second aim of this section is to provide a picture of the baseline distribution of property crime in Santiago before the subway expansion in the mid-2000s. This provides the background for Chapter 6 analysis of the impact of better urban transport accessibility on property crime.

2.3.3 Property crime

How is property crime distributed in Santiago? Does property crime correlate with urban transport accessibility to the central business district? The aim of this section is to provide a preliminary analysis of these two questions. In Chapter 6, I provide a more nuanced answer to the second question by using panel data and a quantitative analysis.

To respond to the first question, it is useful to think of how different theories can help us predict what the property crime distribution in a city will be like. First, a large body of literature on criminology tests whether criminals are more prone to commit crimes near their places of residence compared to places away from their places of residence. The hypothesis that criminals prefer to commit crimes nearer to rather than farther from their homes is known as the 'distance decay theory'. Using aggregate data, Capone and Nichols in Miami (1976) and Rattner and Portnov (2007) in Israel find that crime is more frequent nearer the offender's home. However, Koppen and Keijser (1997) point out that even if individuals would increase their crime rate with distance, the spational distribution of aggregate data would still show a distance-decay shape. If the distance decay hypothesis were correct, we would expect to see more property crimes in the areas where people more prone to commit crime live. Second, as I discuss in the introductory chapter, following the seminal contribution by Gary Becker (1968), the rational choice hypotheses state that there is a trade-off between legal and illegal work. According to this framework, individuals with better employment opportunities, which in turn are correlated with the location of the individual and with the individual's human capital, have fewer incentives to engage in property crime. Third, because an affluent property crime target (an individual or a dwelling) is theoretically more attractive than a less affluent one, household or individual affluence of the target could positively affect property crime rates. However, an affluent household may potentially invest more on security than a less affluent one. Hence, whether the affluence of the target has a positive or negative effect on property crime rates is an empirical question. In fact, while Tseloni et al. (2004) find that household affluence is associated with higher burglary rates in the UK, the same authors find that household affluence is associated with lower burglary rates in the USA.

The joint implication of the distance decay and rational choice perspectives is that we should expect to see more property crime in areas where employment opportunities are scarce. This is because the opportunity cost of crime is lower in these areas and individuals tend to commit crimes near their residence. The affluence of the area (affluence that is also correlated with employment opportunities but is not identical to it) could also affect property crime rates, but in a context-dependent way.

As discussed in Section 2.3.1, the areas where individuals have fewer employment opportunities are in Santiago's south- and east-ends. Hence, all else being equal, I expect higher crime rates in Santiago's southern and eastern metropolitan peripheries. In the specific case of burglary, I also expect that the density of dwellings should also affect the density of burglary. Therefore, all else being equal, burglary should be higher in municipalities with a denser residential population. As shown in Fig. 2.3, the densest municipalities in terms of population are in the eastern and southern peripheries of the 2001 subway network.

My second question was whether there is a correlation between urban transport accessibility and property crime rates. The prediction of theoretical models about the effect of transport accessibility on crime rates is ambiguous on this point. Proximity to the subway network implies easier access of potential offenders to the area with better transport accessibility. In addition, in the case of robbery and larceny, better transport accessibility also implies a higher density of targets of property crime around the subway stations. Both predictions imply a positive association between better urban transport accessibility and property crime rates. On the other hand, better transport accessibility may also imply more 'eyes on the street' that could deter crime due to a higher probability of the on-going crime being reported to the police (Jacobs 1961). This last factor would imply a negative association between transport accessibility and property crime rates. Given the theoretically negative and positive impacts of better urban transport accessibility on property crime rates, the sign of such impact is also an empirical question.

Fig. 2.23 shows the distribution of the density of reported burglary to the police in Santiago.[7] This figure shows that there are more reports of burglary in the city's central business district relative to reports of burglary in the city's periphery. This is not in line with the joint prediction of the distance decay and rational choice theories or with the prediction that there would be more burglary in those municipalities with a higher population density. The pattern in Fig. 2.23 is consistent with the prediction of higher property crime rates in places where the targets (dwellings) are more affluent and, hence, more attractive. On the other hand, the pattern in this figure does not show a visual correlation between proximity to the subway network and burglary.

[7] For the definition of burglary, see the glossary of terms.

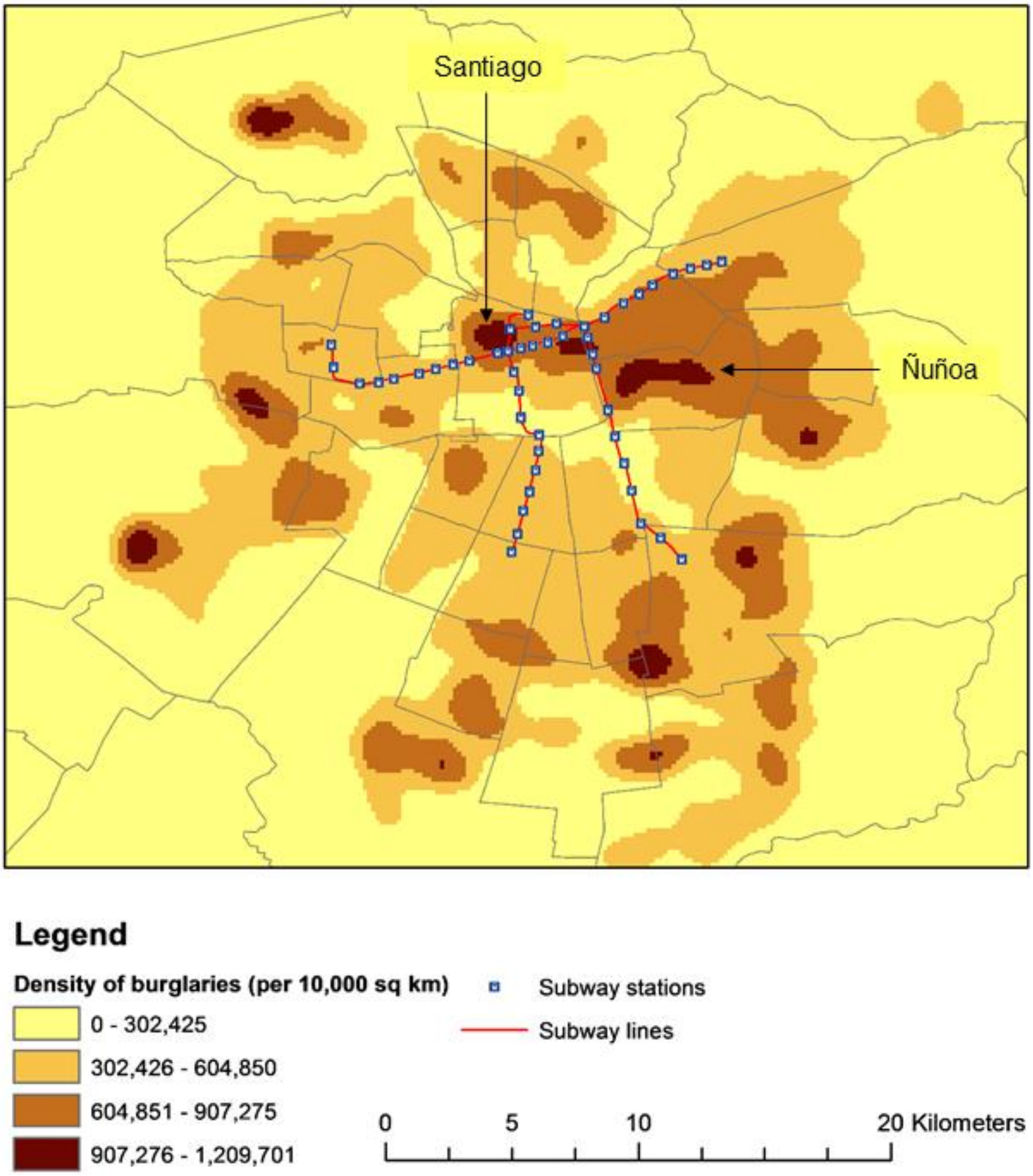


Fig. 2.23 Density of burglary recorded by the police and Santiago's subway network in 2005 (before the expansion of the subway network in the mid-2000s). Note: Author's estimates are from Chile's Subsecretaria de Prevención del Delito data. The density of burglary is an interpolation of the number of burglary per unit of area. This is a kernel interpolation with barriers with an Epanechnikov kernel of bandwidth 2.7 km.

One important difference between burglary and the joint category of robbery and larceny is that, while in the former category, the targets (dwellings) are immobile, in the latter category the targets (people) are mobile. Does this imply that the spatial distribution of reported crime in Santiago for immobile and mobile targets might be different?

Fig 2.23 shows the density of robbery and larceny in Santiago.[8] Both panels in this figure show a high visual association between proximity to the subway network and robbery or larceny. Hence, this figure provides cross-section evidence that urban public transport accessibility may have a stronger effect on the spatial distribution of robbery and larceny than on the spatial distribution of burglary. Fig. 2.23 also provides visual evidence that, insofar as workers who are commuting to their jobs using the subway network are attractive targets of crime, the attractiveness of the areas close to the subway network for likely offenders is positively related to the property crime rate. By contrast, this figure does not visual provide evidence in favour of the joint prediction of the distance decay and rational choice theories; these theories imply that there should be more property crime in the southern and eastern metropolitan peripheries.

Panel A. Density of robbery in Santiago. *Panel B. Density of larceny in Santiago.*

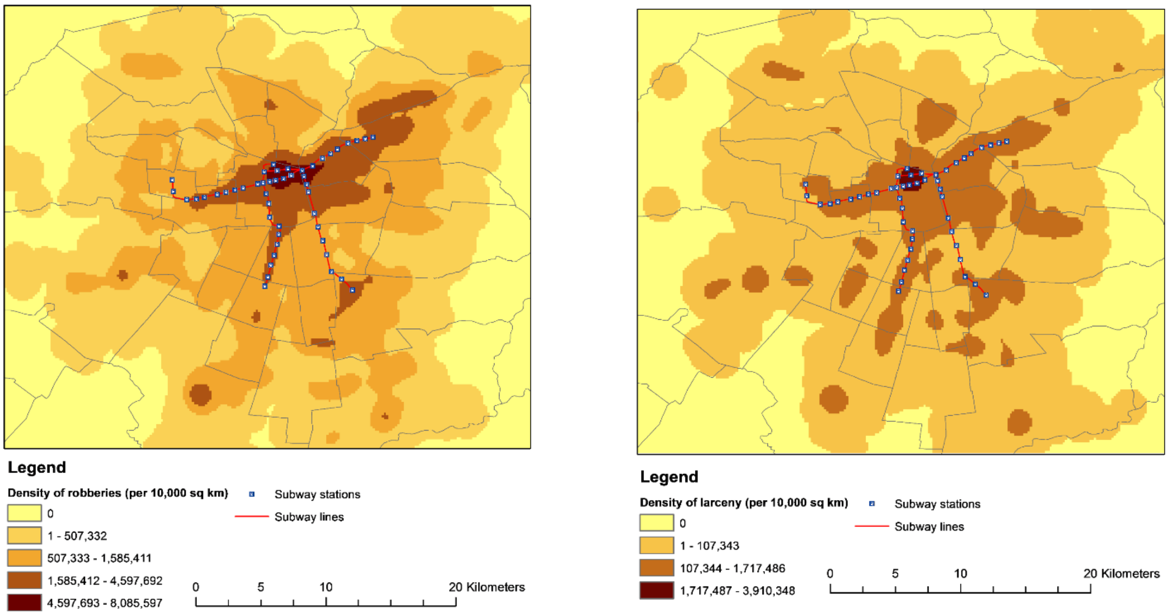


Fig. 2.24 Density of robbery and larceny recorded by the police and Santiago's subway network in 2005 (before the expansion of the subway network in the mid-2000s). Note: Author's estimates are from Chile's Subsecretaria de Prevención del Delito data. The density of burglary is an interpolation of the number of burglaries per unit of area. This is a kernel interpolation with barriers with an Epanechnikov kernel of bandwidth 2.7 km.

My findings in this section are consistent with the hypothesis that the attractiveness of the targets of property crime is a crucial factor in property crime rates. In the case of burglary, the most attractive destinations with a relatively high density of dwellings are in high-income,

[8] For the definition of robbery and larceny, see the glossary of terms.

centrally located municipalities like Santiago and Ñuñoa (see Fig. 2.23). However, in the case of robbery and larceny, the most attractive targets move and there is a high spatial concentration of them in the central business district and around the subway network (see Fig. 2.23).

2.4 Summary and conclusions

What does this chapter tells us about how generalisable the conclusions from Chapters 4, 5 and 6 are? As argued in the context of Amsterdam by Van Praag and Baarsma (2005), there are several facts that suggest that Santiago's housing market is not in equilibrium. As pointed out in Section 2.3.2, two thirds of dwellings built in Chile between 1976 and 2007 were publicly subsidised. This, plus the fact that beneficiaries of publicly subsidised dwellings in Chile were not allowed to sell their dwellings within the first five years generated frictions in Chile's housing market.

Other factors affecting 'dwelling immobility' also contributed to a lack of equilibrium in the market. For example, in 2002, 76 per cent of all dwellings in Chile were owned by their residents. These frictions or 'dwelling immobility' in Chile are documented by Simian (2010) and in the international literature (see, for example, Helderman et al. 2004).

Hence, most likely, unlike in other cities, many citizens in Santiago with low income but high chance of being employed live in the metropolitan edge because the government gave them housing in that specific location (not because they chose that place). If this conjecture were true, could this mean that the impacts of better transport accessibility estimated in Chapters 4, 5, and 6 are likely to be different in other contexts? Most likely, the external validity of my findings depends on the socioeconomic dimension. The impact of better urban transport accessibility on the probability of being employed could be higher in Santiago than in cities with a housing market in equilibrium. Due to rigidities in the housing market, we could hypothesise that citizens in Santiago's metropolitan edge have a higher elasticity between commuting costs and the probability of employment (or, more generally, other labour market outcomes) relative to citizens living in cities whose housing market is in equilibrium. The reason is that, in cities with housing markets in equilibrium, Alonso's monocentric model would predict that individuals with a high elasticity between commuting costs and probability of employment are probably more prone to live nearer the central business district relative to individuals living in cities with a high dwelling immobility.

Similarly, the magnitude of the impact of better urban transport accessibility on high school academic achievement could also be higher in contexts of high dwelling immobility. The reason is that in Santiago there could be a larger proportion of families living in the metropolitan edge with an above-average belief about the magnitude of the impact of better urban transport accessibility on their socioeconomic conditions relative to the same proportion of families living in cities with a low dwelling immobility.

The external validity of the results related to crime (Chapter 6) depends on the type of crime. The results of Chapter 6 on crime to immobile targets such as burglary are more applicable to contexts with a high degree of dwelling immobility. One potentially relevant mechanism for the effect of better urban transport accessibility on burglary in cities with a high degree of dwelling mobility could be through a change in the socioeconomic composition of residents due to the transport improvement. For example, wealthier residents are likely to invest more in security (decreasing burglary) and their dwellings are more attractive targets for burglars (increasing burglary). However, the channel of changes in the composition of residents is less likely to be relevant in cities with a high dwelling immobility. The results of Chapter 6 on crime to mobile targets are also more applicable to contexts with a high degree of dwelling immobility. Wealthier residents, insofar they commute by car (as opposed to public transport) are less likely to be robbed as pedestrians, but their car is more likely to be robbed relative to poorer residents.

This chapter also provides a snapshot of the socioeconomic conditions in Chile and Santiago before, during and after the period of interest (early and mid 2000s). Economic inequality is persistent in Chile and Santiago. Despite a sizable reduction in its poverty rate using an absolute cut-off and an important reduction in economic inequality experienced by Chile in the last three decades, the country is still within the 12 per cent of the most unequal countries in the world according to its Gini coefficient. Moreover, Santiago is even more unequal compared to Chile in terms of household income.

In addition, in 2001—the baseline year for Chapter 4—Chile's employment rate was one of the lowest in the OECD. A low employment rate among women and individuals in the lowest income quintiles relative to other Latin American middle-income countries drove Chile's low employment rate. Moreover, in 2009, Chile exhibited extremely high 'employment inequality' measured as the ratio of the employment rate in the richest tenth to the employment rate in the poorest tenth. As argued by Velasco and Huneeus (2012), Chile's high employment inequality is suggestive evidence that inequality in access to employment between advantaged and disadvantaged households is one of the main factors behind Chile's high income inequality.

On the other hand, Chile has one of the highest correlations between socioeconomic status and test scores in ninth grade (for 15-year-olds) among all countries who took the PISA in 2009 and 2012. Moreover, this correlation is even higher in Santiago than in Chile. Given the centrality of human capital accumulation in future earnings (Card and Krueger 1992; Angrist and Krueger 1991), the previously described high correlation suggests that Chile and its capital city are currently trapped in a cycle of inequality in access to employment, income, and human capital acquisition. Chetty, Hendren, Kline and Saez (2014) conclude that high residential segregation, income inequality and worse primary schools among other factors decrease intergenerational mobility. As discussed in this chapter, these three factors are present in Chile's context. Hence, my preliminary findings that portray an unequal distribution of current and future income generation are consistent with the findings of Chetty et al.

In addition, individuals of lower socioeconomic status in Chile not only have to endure living in a highly unequal society in terms of income, employment, and schooling, but also are more likely to perceive that crime is increasing in their neighbourhoods relative to the perception of individuals of higher socioeconomic status. This, most likely, decreases the well-being of individuals of lower socioeconomic status.

In this bleak picture of socioeconomic and spatial inequality, are there any policies that could improve socioeconomic outcomes in Santiago? One policy option could be to provide low income-households with subsidised housing in neighbourhoods nearer to employment and better schooling opportunities. Another policy option could be to decrease commuting costs (including travel time) from low-income neighbourhoods on the periphery of the city to areas of high employment density and better schooling opportunities. It is the second option that Santiago chose to implement beginning in 2001. In Chapters 4, 5, and 6, I explore whether a massive improvement in Chile's subway network had any impact in labour market, academic achievement and crime outcomes.

Chapter 3
Methods

3.1 Measurement issues

The definition of transport accessibility which the British Department for Transport (2011) uses is the 'extent to which individuals and households can access day to day services, such as employment, education, healthcare, food stores and town centres.' (2011, 2). According to this definition, accessibility is intimately related to the cost (in time, money, and effort) incurred by individuals when accessing their routine activities. In this thesis, the relevant day-to-day activities are workers' access to employment, students' access to nearby schools, and potential offenders' access to targets for crime. The impact on these activities will be discussed in detail in Chapters 4, 5, and 6 respectively.

The British Department for Transport's definition of accessibility implies costs in terms of time, money, and effort to get from origin to destination. I call this 'destination accessibility'. Ahlfeldt (2013) uses destination accessibility when considering the change in travelling distance of workers to all potential employers. However, to apply the destination accessibility concept to the present study, I should model the whole transport network with its different modes (walking, car, bus, subway) and car availability during different periods of the day. Alternatively, I could assume that each individual has only two modes of transport available: subway or walking (and a combination of both modes). I call 'subway accessibility' to an indicator that is inversely proportional to the average time that each individual would take to every potential employer in the city when the only available modes of transport are subway and walking. In the context of Chapter 4, to calculate a subway accessibility measure for each individual, I would need the location of every employer (or cluster of employers) in Santiago. In Chapter 5, I would need to define all schools at a feasible commuting distance for each student. In Chapter 6, I would need the location of the residence of criminals in Santiago. Unfortunately, the criteria for defining 'feasible commuting distance' for students in Chapter 5 requires a very specific knowledge about individuals. In the context of Chapter 4, I do not know of datasets with the addresses of employers (or clusters of employers) for Santiago. In addition, in the context of Chapter 6, I do not have the criminals' address.

A third option is to use the distance between each worker's residence, school or crime area and the nearest subway station as a proxy for access. I call this 'station accessibility'. The advantage of using station accessibility is that it does not require knowledge, data or assumptions about modes of transport other than the subway. In the context of the impact of better urban transport accessibility on property prices, Ahlfeldt (2013) finds similar results using both definitions of accessibility. Because of data availability, in this thesis I use the station accessibility definition.

3.2 Methodological framework

This section discusses the methods for quantifying the impact of better urban transport accessibility on socioeconomic outcomes. To provide a basic reference point I start by describing a simple cross-section regression for studying such relations. Then I describe an individual fixed-effects regression that accounts for unobserved fixed characteristics of each worker, school or crime area depending on the chapter. Finally, I address the general issues that could bias my fixed-effects estimates of the impact of better urban transport accessibility on socioeconomic outcomes.

I start by describing a simple regression model relating the outcome of interest to urban transport accessibility proxied by proximity to the subway network. The outcomes of interest are labour market outcomes, education test scores, or property crime rates. Below is the model that has been often used to study the relation between accessibility and socioeconomic outcomes (see, for example, Dickerson and McIntosh (2013) for an application to education):

$$y_{it} = d_{it}\beta + f_i + g_t + \varepsilon_{it} \qquad (i = 1, \dots, N;\ t = 1, \dots, t), \tag{3.1}$$

In (3.1), y_{it} is the outcome of an individual or area *i* in period *t*, d_{it} is the distance between unit *i* and its nearest subway station at time *t*, f_i are individual unobserved characteristics that are fixed over time, g_t are general time effects and ε_{it} is equation (3.1)'s error term. The key parameter in equation (3.1) is β, the effect of proximity to the subway network on the outcome of interest.

The problem with equation (3.1) is that there could be unobserved characteristics such as a worker or student's ability, or the area's attractiveness for property crime that could be correlated both with the outcome of interest and the proximity to the subway network. This could happen if, in Chapter 5 for example, schools with a high proportion of students from higher socioeconomic status households were located nearer to the subway stations compared to schools with a high proportion of students from lower socioeconomic households. If this were the case, an analysis based on (3.1) would suffer from omitted variable bias.

To account for unit *i*'s unobserved fixed characteristics whose effects do not change over time (variable f_i in equation (3.1)) I work with time differences instead of a cross-section. To study the effects of variation in the key variable (accessibility or distance between schools and their nearest subway stations), models based on time differences need variation in the key variable that—conditional on the regressors—is uncorrelated with the dependent variable's (test scores) trend. As I explain in Chapter 2, one of the largest changes in Santiago's subway network occurred in the mid-2000s. This subway expansion consisted of a new 24-km subway line (Line 4) that goes from the central business district to the south of Santiago, plus extensions of existing subway lines in the northern and southern peripheries of Santiago (Lines 2, 4A and 5). This massive change in transport accessibility decreased the distance from the nearest subway station for more than 50 per cent of households in Santiago. I exploit these transport innovations as well as large-scale panel datasets described in each chapter to identify the impact of proximity to the subway network on socioeconomic outcomes.

A convenient way to estimate equation (3.1) is to rewrite it in time-differenced form:

$$(y_{i1} - y_{i0}) = (d_{i1} - d_{i0})\beta + (g_1 - g_0) + (\varepsilon_{i1} - \varepsilon_{i0}) \tag{3.2}$$

In contrast with equation (3.1), equation (3.2) does not contain the unit *i*'s unobserved characteristics that are time-invariant (f_i) yet still contains the parameter of interest, β. The two periods are before the construction of the new subway stations (t=0) and after their construction (t=1).

Equation (3.2) is an explicit way of specifying a 'before and after' analysis that enables us to identify the key parameter β accounting for invariant characteristics of individuals: $\hat{\beta}$ is the fixed-effects estimator. The identifying assumption for an unbiased estimate of the effect of closer proximity to the subway network on each socioeconomic outcome is that, conditional on individuals' invariant characteristics, the change in unobservables for an individual, student or crime area $(\varepsilon_{i1} - \varepsilon_{i0})$ must be uncorrelated with the distance reduction to the subway network $(d_{i1} - d_{i0})$. This assumption could be violated if, between the baseline and post-subway expansion periods, differential shocks on socioeconomic outcomes could have affected individuals who would experience different magnitudes of distance reduction to the subway network. For example, in Chapter 4, the identifying assumption would be violated if individuals who would experience a large distance reduction to the subway network in the mid-2000s experienced a sustained increasing trend in the probability of being employed before and after the opening of the new subway stations relative to the same probability for individuals who would not experience such a distance reduction to the subway network.

One way of relaxing the identifying assumption is to assume that the change in unobservables affecting outcomes is uncorrelated with the distance reduction to the subway network only for units of similar baseline characteristics. To implement this assumption, in equation (3.2), I control for several baseline characteristics. These controls for baseline characteristics of the individuals allow the fixed effects estimator to compare the outcomes of specific individuals not with the whole sample, but only with those individuals with similar baseline characteristics. For example, in the case of labour market outcomes (Chapter 4), the baseline characteristics of individuals are comprised of salary at the individual's main job, total household income, years of schooling, whether the contract was indefinite or fixed-term, marital status, type of health insurance, whether the person had health problems during any of the four years before the interview, type of home tenure, number of rooms in the household, and the perception of those interviewed about the evolution of their neighbourhood during the past five years with respect to business premises, schools, streets, and sidewalks. All regressions include the linear and quadratic terms of continuous variables and dichotomous variables for discrete characteristics. After controlling for these baseline characteristics, the empirical specification is as follows:

$$y_{i1} - y_{i0} = (d_{i1} - d_{i0})\beta + (g_1 - g_0) + x'_{i0}\,\gamma \ + (\varepsilon_{i1} - \varepsilon_{i0}) \qquad (i = 1, \ldots, N), \quad (3.3)$$

where x'_{i0} is a vector that contains all previously mentioned baseline characteristics.[9]

A more general specification allows for the possibility that a distance reduction to the subway network for a unit (worker, student, or crime target) that ends up at a certain threshold distance (e.g. walking distance) from a subway station could have a larger impact than the same distance reduction for a unit that ends up several kilometres away from the subway network. To allow for such flexibility, in the spirit of Gibbons and Machin (2005), I interact the distance from the subway network with an indicator function that takes value one when the unit is at a maximum threshold from the new subway stations and zero otherwise. In Chapters 5 and 6, I choose two kilometres as the threshold distance by considering feasible walking distances to the nearest subway station (0-3 km) and maximising the equation's R-squared in 0.5 km grids. This ended up being the same threshold (walking) distance used by Gibbons and Machin (2005) and Ahlfeldt (2013). Following the same procedure in Chapter 4, where I work with distances

[9] Including x'_{i1}in the equation in first differences is equivalent to incorporating $h_{it}x'_{it}$in the levels equation where $h_{it} = I\{t = 1\}$ is an indicator function that takes value one during the first period, zero otherwise.

aggregated at the municipality level, the resulting threshold distance is one kilometre. Defining the indicator function as $h_{it} = I(d_{it} \leq threshold\ distance)$, where $I(\dots)$ equals one when the condition in parentheses is true and zero otherwise, I have

$$(y_{i1} - y_{i0}) = (d_{i1} - d_{i0})h_{i1}\beta_1 + (d_{i1} - d_{i0})(1 - h_{i1})\beta_2 + x'_{i0}\gamma + (g_1 - g_0) + (\varepsilon_{i1} - \varepsilon_{i0}) \tag{3.4}$$

In equation (3.4), β_1 is the impact of closer proximity to the subway network on the outcome of interest.

Equations (3.1) through (3.4) assume that the effect of distance reduction to the subway network $(d_{i1} - d_{i0})$ on the outcome variable is linear (i.e. the marginal effect is the same for units which experience a one or a ten kilometre distance reduction). However, there are no theoretical reasons to assume that such effect is linear. One way for allowing non-linear effects is to categorise units according to their distance reduction. In this case, the time-differenced model that allows for non-linear effects of distance reduction on each outcome of interest is:

$$(y_{i1} - y_{i0}) = \sum_j c_j\, h_{i1}\beta_{1j} + \sum_j c_j\,(1 - h_{i1})\beta_{2j} + x'_{i0}\gamma + (g_1 - g_0) + (\varepsilon_{i1} - \varepsilon_{i0}) \tag{3.5}$$

In (3.5), c_j are dummy variables, one for each of the j non-reference categories of distance reduction.

3.3 Identification strategy

I argue that changes in proximity to Santiago's subway network in the mid-2000s are a shock to urban transport accessibility that is exogenous to changes in each of the outcome variables (labour market, academic achievement and property crime as discussed in Chapters 4, 5, and 6 respectively). This argument is conditional on baseline observable characteristics such as distance from the pre-expansion subway network and other baseline characteristics that the literature has previously identified as predictive of the dependent variable. Hence, the change in proximity experienced by Santiago's workers, students and crime areas enables me to identify the impact of better urban transport accessibility on labour market outcomes, academic achievement and crime.

One could claim that a source of endogeneity in the relation between the increase in proximity to the subway network and the socioeconomic outcomes could be the capacity of the municipality's mayors to lobby for the subway to pass through their municipalities. If this capacity to lobby is correlated with the mayor's ability to improve (or worsen) the socioeconomic outcomes in the municipality, the previous concern would be a source of bias in my estimates. In each chapter, using different methods, I control for this potential source of endogeneity. In Chapter 4, I control for citizens' perceptions of the improvement of their neighbourhoods in several dimensions (access to schools, access to shopping facilities, and streets) so this should account for the mayor's capacity to lobby for the subway. In addition, I provide a placebo experiment where I run the fixed-effects analysis using data from two periods before the subway expansion. In Chapter 5, in the first differences regression, I control for the municipality where the school of each student is located, so the concern about endogeneity between proximity to the subway network and academic achievement is not an issue. Finally, the police in Chile are managed at a centralised level so, at least from the point of view of the action of the police on crime, the skills of a mayor or capacity to get more funding should not have a causal impact on the crime indicators in a municipality.

Additionally, as explained earlier, the identification of the effect of proximity to the subway network on socioeconomic outcomes rests on the assumption that there are no variables that are correlated both with the changes in outcomes due to the subway expansion and the distance reduction to the subway network induced by the subway expansion. This assumption could be violated if, for example in Chapter 4, there is a pre-existing trend in which the likelihood of employment for workers with more years of education would be increasing more than the likelihood of employment for workers with fewer years of education. If the citizens' years of education is correlated with the magnitude of the future reduction to the subway network this would bias my estimates.

With suitable data, I can address the previously mentioned concern about the internal validity of the fixed-effects estimates in chapters 4, 5 and 6. To deal with potential pre-existing outcome trends that depend on the pre-subway expansion level of the covariates, in the three empirical chapters I control for several baseline characteristics. The baseline variables for which I control for in each individual fixed-effects regression are discussed in each empirical chapter (Sections 4.2.2, 5.2.2, and 6.2).

In practice, the model that addresses the potentially non-parallel trends for individuals of different baseline characteristics exploits the relation between distance reduction and variation in the outcome variable only for units with the same initial level of baseline characteristics.

Hence, the identifying assumption for the resulting model is that, controlling for baseline characteristics, there are no omitted variables that are correlated with the outcome variable and the distance reduction to the subway network.

The interpretation of the coefficient of interest in equation (3.5) is the intention to treat effect for a national planner who has no control over associated investments. Most of the investments that could have occurred around the new stations such as improvements to parks, streets, and lighting are decided by local governments. Local governments in Chile are elected separately from the central government, so the decisions of the former are autonomous with respect to the decisions of the latter. Other investments such as commercial investment is partly decided by the local governments through each municipality's land use planning and partly by the private firms who decide their own location. Although it would be interesting to explore whether additional investment around the new subway stations are relevant mechanisms for the socioeconomic effects of better urban transport accessibility, to my knowledge, there is no dataset with the information of park improvements, commercial investment or other relevant infrastructure investment in Santiago during the mid-2000s.

Chapter 4

Better Urban Transport Accessibility Improves Labour Market Outcomes

4.1 Introduction

Many governments and non-governmental organisations spend huge amounts of effort and resources trying to improve their citizens' labour market outcomes. All this effort raises an important question about which policies have a causal impact on improving these outcomes. The usual suspects are training schemes, employment subsidies, employment agencies, and policies that affect workers' accessibility to employment.

This chapter investigates specifically the relation between urban transport accessibility and labour market outcomes. As discussed in Chapter 1, sound theoretical considerations supported by evidence suggest that better transport accessibility at the worker's place of residence improves their labour market outcomes. These considerations are related to labour supply, labour demand and the matching between workers and firms.

Several strands in the literature have attempted to determine whether transport accessibility affects labour market outcomes. One strand explores the relation between job proximity and labour market outcomes. Åslund, Östh, and Zenou (2010), using data from Sweden, find that there is a significant impact of job proximity on individual employment and yearly total earnings. They claim that they are able to overcome the endogeneity of the association between commuting time and employment rate by using the policy that refugees in Sweden in the early 90s were allocated in a supposedly random way (conditional on observables characteristics) to locations with different degrees of job accessibility. However, their argument is not totally convincing, because the refugees' locations were in part determined by their desired locations and these desired locations were not part of Åslund et al.'s dataset.

A second strand in the literature analyses the impact of commuting time on labour market outcomes. Gimenez Nadal and Molina (2011) conclude that, conditional on place of residence, one hour of commuting time increases daily working hours by 35 minutes. These authors use lagged and future regional housing costs as instruments for commuting time. However, as these authors note, this study has the limitation that it does not account for potential unobserved heterogeneity between workers (for instance, those commuting more could be more talented). Some authors have found that commuting time is negatively correlated with female labour force participation (see Black, Kolesnikova, and Taylor (2014), who use US data aggregated at the city level) even more than with males in the labour force (Cogan 1981, Gordon 1989). This heterogeneity in the elasticity between commuting time and female employment rate, suggests that in this chapter I should explore the impact of better urban transport accessibility on female labour market outcomes separately from the same impact on the entire working-age population.

A third strand in the literature focuses on the effect of transportation costs on labour market outcomes. Gibbons and Machin (2003) conclude that the opening of the Jubilee Tube Line in South East London at the end of the 1990s slightly increased the number of jobs in firms near the new subway stations in certain economic sectors (e.g. the financial sector). However, transport innovations could affect labour market outcomes not only by increasing firms' demand for workers, but also by decreasing commuting costs to workers living near the new tube line stations. Because Gibbon and Machin's dataset included only firm-level data and not residence-related employment data, the authors could not analyse the effect of the new tube line on the employment rate. Some other researchers have analysed the effect of better transport accessibility on the employment rates of minority workers. Holzer, Quigley and Raphael (2003) conclude that the expansion of the San Francisco rail system increased the hiring of Latinos—but not of African-Americans—by firms near the new stations compared to the hiring of Latinos by firms farther from these stations. They use the rail expansion as a natural experiment that increased transport accessibility for workers to the firms near the new stations. Phillips (2012), using data from a randomised field experiment in Washington DC, finds that a transport subsidy increased the probability that an unemployed job-seeker becomes employed in nine percentage points. Phillips also finds evidence that the mechanism through which workers increased their probability of being employed was an increased intensity and spatial scope of job search.

A fourth strand in the literature analyses whether road construction has an impact on labour market outcomes. Michaels (2008) finds that increased access to the US highway system between 1959 and 1975 led to an increase in the demand for skill. To avoid a potential endogeneity between road construction and demand for labour, Michaels uses the unintended connection to the US highway system of economically small cities as an exogenous shock to accessibility to highways. In addition, Duranton and Turner (2012) find that increases in a city's stock of (interstate) highways in the USA increase employment over the next 20 years in those areas. To avoid the potential endogeneity between road construction and employment, they use planned routes, railroads and exploration maps as instruments for the actually built routes. On another example, Sanchis-Guarner (2012) finds that, while increases in accessibility from work have a positive effect on wages and hours worked, increases in accessibility from home do not have an effect on either outcome. Sanchis-Guarner exploits the construction of new roads in Great Britain in the 2002–2008 period holding workers' home and work locations constant.

In order to measure any impact of transport accessibility on labour market outcomes, I use the average distance between the individuals' municipalities of residence and the nearest subway station ('municipality–subway distance reduction').

The main contribution of this chapter is to use a convincing identification strategy to show that individuals' labour market outcomes (employment status, hours of work, and labour earnings) respond causally to improvements in transport accessibility at their place of residence. My identification strategy exploits changes in transport accessibility induced by a large expansion of the subway network in Santiago (Chile) in the mid-2000s. For a detailed explanation of the subway expansion and my identification strategy, see Sections 2.1.4 and 3.3 respectively. In accordance with program evaluation literature, I refer to the individuals affected by the transport innovation as my 'treated group.' My evaluation method is an individual fixed-effects model that allows for differential trends in labour market outcomes along pre-treatment observed covariates. To allow for such differential trends, as explained in Section 3.3, I incorporate several personal and municipal predetermined characteristics in an ordinary least squares first-differences framework. I also check that the assumption of parallel trends for individuals who experienced different degrees of municipality–subway distance reduction holds in a period before the expansion of the subway network.

My regression estimates are based on an individual panel dataset of people living in the Santiago Metropolitan Region ('Santiago') in Chile. Santiago is an interesting and feasible place for conducting this study because of several reasons. First, as explained in Section 2.1.4, between March 2004 and March 2006, with the inauguration of a new 24-km subway line and eight additional new stations in other lines, Santiago experienced the most important improvement of its urban transport network in thirty years. Second, as explained with more detail in Section 2.2.1, at the time of the subway network expansion, Santiago had an unusually low employment rate, compared both to other Latin American countries and to OECD countries. These two factors make Santiago useful for exploring whether difficulties in access to jobs explain part of the low employment rate in the city. Third, I have a detailed individual panel dataset with the employment status, income, and background characteristics of workers and non-workers living in Chile measured both before and after the subway network expansion. The fact that I work with an individual panel dataset enables me to avoid changes in the composition of individuals in municipalities due to better transport accessibility. I avoid such composition (or selection) effects by estimating the effect on the group that would have received the treatment if the subway stations would have been inaugurated at the same time when they were announced (the announcement was in 2001). In other words, the municipality of residence is determined by the individuals' address information in the pre-treatment period (2001) rather than in the post-treatment one (2006). This kind of estimation is known as an intent-to-treat analysis (Little and Yau 1996). Moreover, in this chapter the focus on intent-to-treat estimates is necessary because the panel has no address information for the post-treatment period.

I find that the employment rate, hours of work, and individual monthly earnings from labour for individuals in the treatment group relative to individuals in the control group increased substantially. In line with the program evaluation terminology, I identify as the 'treated group' those individuals whose municipality experienced an average municipality–subway distance reduction greater than one kilometre and who ended up at a minimum average distance of less than one kilometre from the subway network . In contrast, individuals whose municipality did not experience an average municipality–subway distance reduction and whose municipality in both periods was farther than one kilometre from the subway network comprise the 'control group.' The employment of individuals in the treatment group increased 8.4 percentage points relative to the employment of workers in the control group. This is 14.3 per cent of the baseline employment rate of workers in the treated municipalities. I also find that hours of work for individuals in treated municipalities increased 29.4 hours per month relative to individuals in control municipalities. This is 30 per cent of the average baseline hours of work and, on average, represents 1.4 hours per weekday. Finally, I also find that, on average, the individual monthly earnings from labour for treated individuals increased by US$192 relative to the individual monthly income from work for control individuals.

The remainder of the chapter is organised as follows. Section 4.2 explains my methods. Although these were broadly explained in Section 3.2 and above, Section 4.2 shows the estimation equation and the identification issues that are specific to this paper. Section 4.3 describes the data and the empirical implementation. Section 4.4 presents and discusses my results. Finally, Section 4.5 presents concluding remarks.

4.2 Method

4.2.1 Methodological Framework

In this chapter, my estimation equation is as follows:

$$E_{i1} - E_{i0} = d_i' h_{i1} \beta_1 + d_i'(1 - h_{i1})\beta_2 + (g_1 - g_0) + x_{i0}' \gamma + (\varepsilon_{i1} - \varepsilon_{i0}) \tag{4.1}$$
$$(i = 1, \ldots, N)$$

where E_{it} is either employment status (a 0–1 dummy variable), hours of work, or labour earnings in year t; d_i' is a vector that contains dummy variables: one for each of the non-reference distance reduction to the subway network categories; $h_{i1} = I(distance\ to\ subway \leq threshold\ distance)$, where $I(\ldots)$ is an indicator function that equals one when the condition in the parenthesis is true is and zero otherwise; β_1 is now also a vector of the same length as vector d_i'; and x_{i0}' is a vector that contains all baseline characteristics of individuals. In equation (4.2), the impact of better transport accessibility on labour market outcomes is given by β_1; g_t captures overall employment trends in Santiago during the sample period of my study; the inclusion of individual baseline characteristics x_{i0}' in equation (4.1) enables me to relax the usual fixed-effects identifying assumption by enabling differential employment trends for individuals with different initial characteristics; and ε_{it} represents individual-specific transitory shocks to their employment status.

4.2.2 Identification issues in this individual fixed-effects model

As explained in Section 3.3, the identification of the effect of closer proximity to the subway network on socioeconomic outcomes rests on the assumption that there are no variables that are correlated both with the changes in outcomes due to the subway expansion and the distance reduction to the subway network induced by the subway expansion. This assumption could be violated by at least two reasons. First, if the improvement in subway proximity induces selection due to movement of workers in initially non-treated municipalities into treated areas in the post-treatment period. The individuals' municipality of residence in the CASEN panel dataset corresponds to the municipality of residence in the initial year of the panel (1996). Because the new subway line was announced in 2001, the municipality of residence is not subject to selection due to heterogeneous returns from proximity to the subway network. As pointed out in Section 4.1, in this chapter I estimate an intent-to-treat effect.

Second, as pointed out in Section 3.3, this chapter's identification assumption could also be violated if labour market outcomes (this chapter's dependent variables) did not follow a parallel trend in treated municipalities with respect to control municipalities should the subway network expansion (the treatment) not have taken place. To relax this assumption, as pointed out in a generic way in Section 3.3, in this chapter I control for workers' and their municipalities' baseline characteristics. The baseline characteristics of workers include the worker's initial labour market outcomes (excluding the outcome of interest for avoiding the lagged dependent variable bias issue), years of schooling, age, gender, marital status, health problems, number of rooms of their dwelling, housing tenure, perception of improvement of their neighbourhood, whether the dwelling is in a rural area. The baseline characteristics of worker's municipality include the average initial distance between households in the worker's municipality and the nearest subway station.

4.3 Data and empirical implementation

4.3.1 Data

To identify the effect of better intracity transport accessibility on labour market outcomes we would ideally need a random allocation of individuals in places with different levels of transport accessibility. In reality, individuals and their households sort within a city depending on their individual characteristics. Even though we can control for the individuals' observed characteristics, there will always be unobserved characteristics (like ability and high preference for shorter commutes) that may bias cross-section results. A way to control for unobserved individual characteristics is by having individual panel data before and after a large change in urban transport accessibility that, after controlling for predetermined characteristics, is as good as random. Ideally, we would want a large dataset with individual addresses and socio-demographic information. I am not aware of publicly available panel datasets with individual addresses in contexts of large urban transport innovations in Chile. Given privacy issues, it is much more common to have individual panel datasets with the individual address approximated at some kind of administrative division within a metropolitan area.

I use a detailed individual panel dataset on labour market outcomes and information about individuals' municipalities of residence (35 municipalities in my dataset), level of schooling, health, demographic characteristics, housing, and perceptions of the neighbourhood. This dataset is Chile's 1996, 2001, 2006 Casen Panel dataset (henceforth, 'Casen Panel dataset'. While the 1996 wave was administered in November and December, the 2001 wave was administered in October and November, and the 2006 wave, between November 2006 and February 2007. I restrict my sample to the working age population (15 years old and above as defined by Chile's statistics authorities (Instituto Nacional de Estadisticas, Chile 2010)) in Santiago Metropolitan Region ('Santiago') who responded to the Casen Panel survey in 2001 and 2006, and who were not studying full-time in 2001. I also restrict the sample to predominantly urban municipalities by setting the city limit at 30 km from Santiago's subway network in 2006.[10] The final dataset for my main results is a balanced two-period panel with 2,454 individuals representing approximately 3,349,800 citizens in Santiago.

The Casen Panel dataset is a follow-up of the 1996 cross-section Casen survey. In 1996 and 2001, the Casen Panel dataset sample sizes were 20,948 and 15,038. Hence, there was an attrition rate of 28.2 per cent. In 2006, the sample size was 10,370. Therefore, the 1996 –2006 attrition rate was 50.5 per cent (Bendezú, Denis, and Zubizarreta 2007).

Although the bias due to attrition depends on the context and survey methods, based on previous evidence from the Michigan Panel Study of Income Dynamics ('PSID'), this proportion of attrition is not evidence by itself that the Casen Panel lost representativeness. Fitzgerald et al. (1998) found that after 21 years, the PSID had experienced an cumulative attrition rate of 50 per cent. These authors found that despite this attrition rate, the PSID remained a representative sample of the US population. Moreover, the Casen Panel dataset has longitudinal weights, which restore the representativeness dealing with potential selection on observables in the attrition. However, as in any study that uses panel data, selection on unobservables of attritors that could be correlated with both the treatment and the dependent variable, may limit the generalisation of the conclusions of this study to Santiago's population. However, I have no reasons or knowledge to suppose that in the Panel Casen dataset there was a serious selection on unobservables of attritors. I am not aware of other panel datasets in Chile with labour market outcomes and the information about the municipality of residence with waves both before March 2004 and after March 2006.

Alternatively, I could also use datasets with repeated cross sections before and after the transport innovation. However, because repeated cross-section surveys are administered to (potentially) different individuals in different periods, this type of dataset would not enable me to distinguish the effect of better transport accessibility on labour market outcomes due to

[10] The criterion to set the city limits was to include those municipalities with a high proportion of urban residents. However, the results in this paper are robust to any city limit outside the boundaries of the 2006 subway network.

compositional effects or place-based effects. Following D'Costa et al.'s terminology (2013), while people moving to locations of better accessibility cause the former effect—which may be potentially affected by selection bias—the causal effects on the individuals affected by the treatment are the latter type of effect. Because of their relevance to policy and the cost-effectiveness evaluation of new subway lines, I am interested in identifying the place-based effect.

4.3.2 Empirical implementation

As pointed out in Section 4.2.1, to estimate the impact of better urban transport accessibility on labour market outcomes, ideally, I would need the distance between the residence of each individual and the nearest subway station. Although all household surveys—in particular, the Casen Panel dataset—record the address of each household, due to privacy issues, the information about the households' specific address is not disclosed to researchers in Chile. As a proxy to the households' address of residence, I use the households' municipality of residence. As I mention in the data section, in my dataset, there are 35 municipalities in urban Santiago. Hence, the crucial spatial information about each household in my sample is the average distance between his or her municipality of residence and the nearest subway station.

To calculate a measure of average distance between workers in each municipality and the subway network I need workers' residential addresses. Because the Casen Panel dataset does not have individuals' exact addresses (it only contains their municipalities), I need an alternative dataset with addresses. An alternative dataset that contains addresses is Chile's 2009 University Selection Test 'PSU'. This dataset contains all the students who took Chile's University Selection Test in 2009. Because the PSU dataset only contains households with students graduating from high school in 2008 who opted to take the PSU, the population of the PSU dataset is a subset of Santiago's population. I used this dataset to calculate the average minimum distance of households in each municipality to the subway network before and after the inauguration of the new subway. By using this dataset, I assume that the average distance in each municipality between households with and without a student who took the PSU in 2009 and the closest subway station does not differ systematically. To obtain the previously mentioned household–subway network minimum distances I calculated the Euclidean distance between each of the more than 100,000 households in Santiago in the PSU dataset and each subway station in the city.

4.4 Results

4.4.1 Descriptive statistics

Figure 4.1 shows the distribution of treated and control municipalities. This figure shows that, if I define treated and control municipalities following the criteria described in section 3.2, there is one treated municipality (Macul) and four control municipalities (Pedro Aguirre Cerda, Pudahuel, Cerro Navia and Lo Barnechea). The fact that the number of treated and control municipalities is small could raise concerns on my capacity to carry out causal inference. However, allowing correlation between the labour market outcomes of individuals within the same municipality should solve a potential source of underestimation of standard errors due to spatial correlation between the regression errors. Hence, in all specifications I cluster the standard errors at the municipality level.

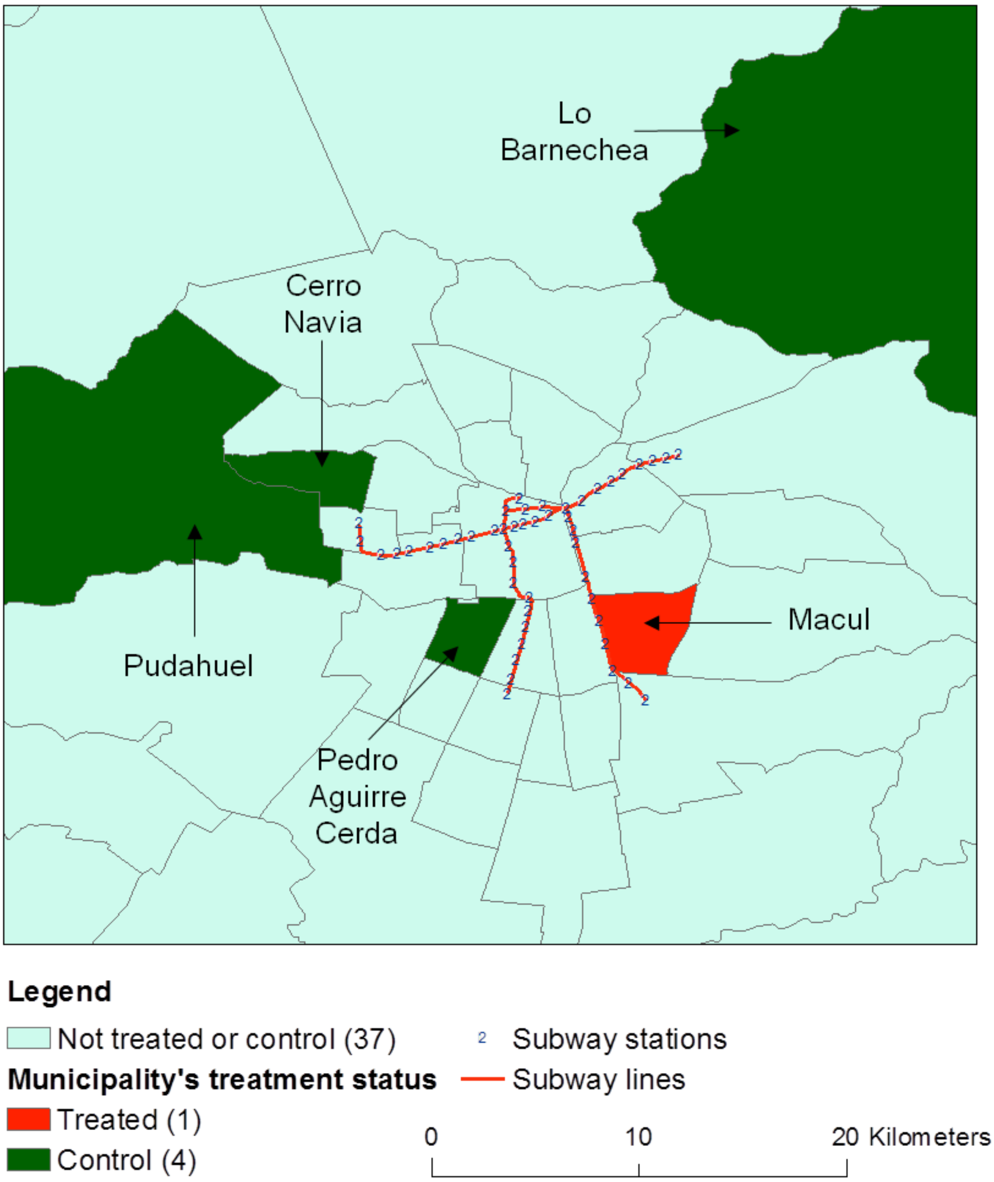


Fig. 4.1 Treatment and control municipalities in Santiago

Table 4.1 reports descriptive statistics for my sample of individuals with weights that make the sample more representative of Santiago's population. Columns (1) through (4) describe the characteristics of all non-student individuals in Santiago aged 15 and over in 2005. 3.3 per cent of individuals in Santiago lived in treated municipalities. The treated municipalities are those that, on average, experienced a distance reduction greater than one kilometre to the subway network and ended up closer than one kilometre from the subway network in 2005. On the other hand, 11.6 per cent of individuals in Santiago lived in control municipalities. Individuals living in municipalities that did not experience a distance reduction to the subway network and were farther than one kilometre from the new subway network in both periods compose the latter group.

Relative to individuals in the control group, individuals in the treated group had 2.2 more years of schooling and were 4.1 kilometres farther from the central business district. In addition, on average, treated individuals were 2.8 km closer to the subway network in 2001 than control individuals. The 2001 employment rates of individuals in the treated and control groups were almost the same: 58.6 per cent and 57.9 per cent respectively and the difference is not significant at conventional test levels. In 2006, the employment rate had increased to 67.9 per cent in the treatment group and to 58.5 per cent in the control group. Hence, the difference in the employment rates between the two groups in 2006 was of about 9.4 percentage points but is not significant at the five per cent level. This may be due to small sample size. These figures suggest a slight improvement in Santiago's labour market during the 2001–2006 period. While hours of work in 2001 were slightly less in the treatment than in the control group (two hours per month), in 2006 individuals in the treated group, on average, worked 31 more hours per month. However, these differences are not statistically significant at conventional levels. In 2001, individuals in the treated group earned US$147 (in 2001 dollars) per month more than individuals in the control group did. This represents a 93 per cent of the average monthly labour earnings in the control group. However, such difference is not statistically significant at conventional levels. In 2006, individuals in the treated group, on average, earned US$382 more per month compared to individuals in the control group. Even though the difference in earnings widened, this difference was not statistically significant at conventional levels.

Table 4.1 Descriptive statistics—means and standard deviations for individuals in Santiago

	(1) Entire population [s.d]	(2) Treated population [s.d]	(3) Control population [s.d]	(4) Diff. (2)–(3) (s.e.)
Share of each group in the entire population	100%	3.3%	11.6%	
Predetermined covariates (2001)				
Years of schooling	9.989	11.31	9.057	2.253**
	[0.176)	[0.956]	[0.588]	(1.123)
Age	44.64	41.79	45.37	-3.574
	[0.605)	[3.084]	[1.688]	(3.516)
Female	0.533	0.520	0.525	-0.00471
	[0.0127)	[0.0988]	[0.0248]	(0.102)
Number of rooms	2.706	2.846	2.781	0.0651
	[0.0613)	[0.138]	[0.157]	(0.210)
Municipality–CBD[a] distance (km)	12.94	6.964	11.10	-4.135***
	[0.501)	[0]	[0.272]	(0.272)
Urban household	0.986	1	1	0
	[0.00273)	[0]	[0]	(0)
Categories of distance reduction				
0-km distance reduction	0.161	0	1	
	[0.0170)	[0]	[0]	
0 km< distance reduction ≤ 1 km	0.385	0	0	
	[0.0227)	[0]	[0]	
1 km< distance reduction	0.454	1	0	
	[0.0220)	[0]	[0]	
Municipality–subway distance (km)				
2001	6.723	1.972	4.757	-2.785***
	[0.461)	[0]	[0.344]	(0.344)
2006	5.348	0.936	4.757	-3.821***
	[0.448)	[0]	[0.344]	(0.344)
Employment rates				
2001	0.574	0.586	0.579	0.00737
	[0.0174)	[0.0865]	[0.0493]	(0.0995)
2006	0.576	0.679	0.585	0.0943
	[0.0165)	[0.0782]	[0.0480]	(0.0917)
Hours of work per month				
2001	99.08	99.23	101.5	-2.286
	[3.111)	[19.18)	[9.734]	(21.51)
2006	89.38	118.7	87.38	31.35
	[3.420)	[22.67]	[10.23]	(24.88)
Monthly labour earnings (2001 US$)				
2001	177.8	305.5	158.7	146.8
	[11.72)	[91.08]	[34.40]	(97.36)
2006	218.4	555.0	173.3	381.7
	[20.69)	[335.4]	[41.42]	(338.0)
Number of individuals in the sample	2,501	97	351	448
Number of individuals in the subpopulation	3,428,915	112,368	398,959	511,327

Notes: Individuals in the treated sample resided in municipalities that experienced a distance reduction to the subway network in 2005 greater than one kilometre and ended up nearer than one kilometre from the subway network. Individuals in the control sample resided in municipalities that did not experience a distance reduction to the subway network in 2005 and in both periods were farther than one kilometre from the subway network. The sample is restricted to working-age population (15 years and older in 2005) who responded to both waves of the Casen Panel Survey and were not full-time students in 2001. All observations are weighted by their longitudinal weights. *** p<0.01, ** p<0.05, * p<0.1.

a. Central Business District.

4.4.2 Main results

Employment rate

In this section, I analyse the impact of transport accessibility on labour market outcomes. First, to uncover the direction of possible biases, I start with a naive cross-section OLS specification (as in equation (3.1)). Then, to quantify the differences in employment rates, hours of work, and income for individuals living in treated and control municipalities observed in Table 4.1, I estimate fixed-effects models that control for the effects of unmeasured individual-specific characteristics like individual ability (as in equation (4.1). In addition, as I explain with more detail in Section 4.2.2, and since I use a panel and an intent-to-treat estimator, I control for the potential migration of individuals with high employability to areas that experienced a distance reduction to the subway network. Table 4.2 reports the estimates assuming a linear effect of proximity to the subway network on employment status and using the sample of all individuals aged 15 and above and excluding full-time students in 2001. Using a basic cross-section OLS specification, column (1) shows the association between proximity to the subway network and the employment rate. Although positive, this association is not statistically significant. Column (2) includes socioeconomic, demographic, and geographic controls. This turns the association between proximity to the subway network and the employment rate negative, but still non-significant in statistical terms. Column (3) allows for heterogeneity in the previously described association. These estimates are still not distinguishable from zero.

Table 4.2 The effect of municipality–subway distance reduction on employment status: linear models

Dependent variable. Columns (1) through (3): employment status in 2001; columns (4) through (6): change in employment status 2001 to 2006	(1)	(2)	(3)	(4)	(5)	(6)
	Cross-section association			Individual fixed effects		
	Basic model	As (1) plus predetermined covariates	As (2), plus heterogeneity in school-subway distance	Basic model	As (4) plus predetermined covariates	As (4), plus heterogeneity in school-subway distance
Proximity to the nearest subway station (km)	0.0884 (0.116)	-0.167 (0.116)		0.572 (0.492)	0.299 (0.694)	
Proximity to the nearest subway station (km) | distance ≤ 1 km			0.491 (0.535)			3.395 (5.833)
Proximity to the nearest subway station (km) | distance > 1 km			-0.125 (0.130)			0.243 (0.687)
Control variables (2001)	No	Yes	Yes	No	Yes	Yes
Observations	2,511	2,464	2,464	2,500	2,453	2,453
R-squared	0.000	0.966	0.966	0.000	0.362	0.363

Notes: The table reports regression coefficients and standard errors multiplied by 100 to give the % effect of a one-point change in explanatory variables. The key variable in columns (1) through (3) is the negative of the minimum distance to the individual's municipality of residence and the nearest subway station. The key variable in columns (4) through (6) is the distance reduction to the nearest subway station because of the new stations between final and initial periods. The dependent variable in columns (1) through (3) is individuals' employment status in 2001. The dependent variable in columns (4) through (6) is individuals' post-treatment (2006) minus pre-treatment (2001) employment status—where people who worked during the previous week are coded with a one, zero otherwise. Hence, columns (4) through (6) provide an individual fixed effects estimate. The sample includes individuals aged 15 and over in 2005 who were not full-time students in 2001. Regressions are run at the individual level and are weighted by the survey's longitudinal weights. The controls are at the individual and municipality levels. At the individual level, these regressions control for the linear and quadratic pre-treatment levels of individual monthly income from work, household total income (including social transfers), years of schooling, age and number of rooms in the dwelling. These regressions also include individual dummies for gender; whether the individual lived in a rural area; five categories of type of contract; six marital status categories; eight health insurance categories; whether the individual had health problems in each of the last five years; twelve home tenure categories; and four categories for each variable of perception of improvement of the neighbourhood during the last five years. At the municipality level, these regressions control for the linear and quadratic average distance between households in each municipality and the central business district (Plaza Baquedano) and the pre-treatment average distance between households in each municipality and their nearest subway station. Robust standard errors clustered at the municipality level in parentheses. Sample restricted to schools at a maximum distance of 30 km from the post-treatment subway network. All regressions include an intercept (not shown). *** p<0.01, ** p<0.05, * p<0.1.

Column (4) is a fixed-effects model with no controls and exhibits the results for specification (3.2). The results in this column show that there is a positive but non-significant association between municipality–subway distance reduction and the 2001–2006 change in the employment rate. Column (5) of Table 4.2 shows the estimates of specification (3.3), which allows for differential trends for the extensive set of predetermined covariates mentioned in Section 4.2.2. In qualitative terms, the estimate of the coefficient on distance reduction in column (5) does not differ with respect to the estimate in column (4). In column (6), I allow for heterogeneity in the effect of distance reduction depending on how close the municipality was to the 2006 subway network (specification depicted by equation (4.1)). In this column, the coefficient on distance reduction increases substantially to 3.4 percentage points per kilometre of additional proximity to the subway network (a coefficient of 3.395). This is suggestive evidence that the cross-section estimates are biased downwards. In addition, because the standard error increases almost ten-fold between columns (5) and (6) of Table 4.2, the estimate on column (6) is not statistically significant. One reason for these large standard errors could be that the linear specification potentially masks important non-linearities in the effects of municipality–subway distance reduction on the employment rate. These results are robust to the use of two kilometres as the distance threshold (as in Chapter 5 and Chapter 6; see Table A10.1 in the Appendix).

Table 4.3 shows the estimates from equation (4.1), which allows for a non-linear relation between municipality–subway distance reduction and the employment rate. Column (1) considers all working age individuals in 2005 who were not full-time students in 2001. According to this estimate, the effect of the treatment is an increase in probability of employment by 7.3 percentage points in 2006 (a coefficient of 7.265). This is extremely high if we consider it is a 12.4 per cent of the employment rate in 2001 of treated individuals (the employment rate of treated individuals in 2001 was 58.6 per cent).

In the introductory section to this chapter (Section 4.1), I mentioned that there is previous evidence that the elasticity between commuting time and employment rate is higher for females than for the whole population. Additionally, in Chapter 2, I show that Chile's female employment rate in 2001 (this chapter's baseline year) was the lowest in the OECD and one of the lowest in Latin America. Due to the previous evidence and how low the female employment rate in Chile was, in 4.3's column (2) I analyse the impact of proximity to the subway network on the female employment rate. The results in this column show that the estimate of the key coefficient on distance reduction when the sample is restricted to women is 18 percentage points (a coefficient of 17.78). Interestingly, the key coefficient in Table 4.3's column (3) (coefficient of –1.888) shows that the increase in the employment rate for men is not statistically significant. This is suggestive evidence that the positive effect of distance reduction on the employment rate is driven by the effect on women.

Table 4.3 The effect of municipality–subway distance reduction on employment status: nonlinear models

Dependent variable: change in employment status 2001 to 2006	(1) All individuals	(2) Women	(3) Men
Post-treatment municipality–subway distance ≤ 1 km			
1 km< distance reduction	7.265**	17.78***	-1.888
	(3.502)	(4.595)	(5.488)
0 km< distance reduction ≤ 1 km	-2.352	-1.785	-5.025
	(6.603)	(7.931)	(5.669)
0 km distance reduction	4.455	6.176	-3.668
	(3.944)	(5.151)	(4.736)
Post-treatment municipality–subway distance > 1 km			
1 km< distance reduction	0.863	2.537	-1.262
	(2.943)	(4.922)	(3.005)
0 km< distance reduction ≤ 1 km	-4.832*	-5.811	-4.236
	(2.798)	(4.790)	(3.709)
0 km distance reduction (reference category)	0	0	0
	(0)	(0)	(0)
Observations	2,453	1,361	1,092
R-squared	0.366	0.343	0.502

Notes: As for Table 4.2. *** p<0.01, ** p<0.05, * p<0.1.

Hours of work

To provide a more complete picture about the effects of better transport accessibility on labour market outcomes I also explore the impact on hours of work. Table 4.4 depicts the effect of municipality–subway distance reduction on the intensive margin of employment. In this table, I consider that the non-employed population works zero hours. Column (1) of Table 4.4 shows the estimates for the whole population. The coefficient on the treated group is 28.71 hours per month. This means that the effect of the inauguration of the new subway stations implied an increase of 29 hours of work per month. Since this represents a 30 per cent of the average baseline hours of work and, on average, represents 1.4 hours per weekday, the effect on hours of work is large.

Table 4.4 The effect of municipality–subway distance reduction on hours of work: nonlinear models

Dependent variable: change in monthly hours of work 2001 to 2006	(1) All individuals	(2) Women	(3) Men	(4) As in (1) restricting sample to employed in both periods
Post-treatment municipality–subway distance ≤ 1 km				
1 km< distance reduction	28.71***	57.98***	6.632	39.00***
	(7.333)	(9.975)	(13.92)	(10.29)
0 km< distance reduction ≤ 1 km	8.270	19.51	-8.778	6.785
	(11.73)	(16.33)	(8.919)	(11.47)
0 km distance reduction	23.31	29.06	-6.929	33.79
	(14.51)	(18.84)	(10.26)	(22.44)
Post-treatment municipality–subway distance > 1 km				
1 km< distance reduction	3.891	9.654	-0.700	-4.015
	(6.930)	(10.03)	(8.707)	(8.710)
0 km< distance reduction ≤ 1 km	-3.953	-0.128	-9.485	11.02
	(5.566)	(9.292)	(6.795)	(8.529)
0 km distance reduction (reference category)	0	0	0	0
	(0)	(0)	(0)	(0)
Observations	2,078	1,210	868	744
R-squared	0.274	0.293	0.391	0.213

Notes: As for Table 4.2. *** p<0.01, ** p<0.05, * p<0.1.

One could argue that this estimate is confounding the effect of distance reduction on the extensive margin of employment (employment status) with the effect on the intensive margin of employment (hours of work). In other words, the increase of hours of work may be solely due to the increase in the employment rate and not due to increases in weekly hours of work for treated individuals. To explore the validity of this critique to the estimate in column (1), I restrict my sample to those individuals who worked in both periods (2001 and 2006; see column (4) of Table 4.4). Not only does the coefficient on hours of work not go down, but it actually goes up. However, this coefficient should be interpreted with caution because the sample selection is endogenous to the treatment (i.e. we know that the distance reduction affected the employment rate of the treated group in 2006).

Labour earnings

I also explore the effect on individual labour earnings. In Table 4.5, I assign zero labour earnings to the non-working population. An alternative way would have been to constrain my sample to workers with positive earnings in both years. The problem of this alternative approach is that this sample would suffer from selection. We know from the subsection on the employment rate that one effect of increased proximity to the subway network was an increase in the employment rate for treated individuals. Column (1) in Table 4.5 shows that the effect of the treatment assigning zero labour earnings to the non-working population was to increase average earnings in the treated group by US$185.4. Since this is 61 per cent of the average treated group's baseline individual income from work, the effect of the treatment on labour earnings was substantial.

Table 4.5 The effect of municipality–subway distance reduction on individual labour earnings: nonlinear models

Dependent variable: change in monthly individual labour earnings 2001 to 2006 (in 2001 US$)	(1) All individuals	(2) Women	(3) Men
Post-treatment municipality–subway distance ≤ 1 km			
1 km< distance reduction	185.4***	-116.8***	481.0***
	(37.96)	(32.90)	(103.8)
0 km< distance reduction ≤ 1 km	-21.29	-66.31	15.58
	(37.41)	(42.12)	(57.00)
0-km distance reduction	-14.83	-11.80	-1.654
	(36.01)	(40.97)	(43.28)
Post-treatment municipality–subway distance > 1 km			
1 km< distance reduction	-23.97	-12.06	-22.57
	(30.30)	(40.47)	(41.13)
0 km< distance reduction ≤ 1 km	-2.841	-40.84	49.26
	(26.17)	(35.44)	(34.06)
0-km distance reduction (reference category)	0	0	0
	(0)	(0)	(0)
Observations	2,464	1,366	1,098
R-squared	0.147	0.268	0.233

Notes: As for Table 4.2. *** p<0.01, ** p<0.05, * p<0.1.

On the other hand columns (2) and (3) in Table 4.5 show that, while women's average income from work decreased by US$116.8 per month, the same figure for men increased by US$481.0 per month. In section 4.4.4, I discuss some evidence that might explain these two contrasting results.

Hence, there is a consistent effect of municipality–subway distance reduction on individuals' employment status, hours of work, and income from work.

4.4.3 Robustness analysis

There are at least two reasons why my preferred estimates in the previous section could be biased. First, there could be pre-existing labour market trends in treated areas. Second, if the attrition in the sample is correlated with unobservables, and these unobservables are correlated with the outcome variables, this could also be biasing my results.

4.4.3.1 Falsification check: there were no pre-existing differing trends between treated and control areas

A pre-subway expansion increasing-trend in the employment rate of women in municipalities that would experience a large increase in proximity to the subway network could be biasing my results. To test for such possibility, I run the same analysis as in Table 4.3 using data before the subway expansion. This is known as a falsification check or placebo experiment in the program evaluation literature.

Tables 4.6 and 4.7 show the same regression depicted in column (1) of Tables 4.3 and 4.4, but using the 1996–2001 pre-intervention data. Column (1) in Tables 4.6 and 4.7 shows the estimates of the specification in equation (4.1). The coefficient on the treated category (a municipality–subway distance reduction larger than one kilometre and a distance from the subway network smaller than one kilometre) is not significant at conventional levels. This means that the increase in the employment rate (Table 4.6) and hours of work (Table 4.7) after the expansion of the subway network in the mid-2000s in Santiago is not explained by a pre-existing trend that could be violating the differences-in-differences common trends assumption between treated and control individuals.

Table 4.6 Falsification check using data before the inauguration of new subway stations only: employment status

Dependent variable: change in employment status 1996 to 2001	(1) All individuals	(2) Women	(3) Men
Post-treatment municipality–subway distance ≤ 1 km			
1 km< distance reduction	1.864	-5.009	7.611*
	(4.535)	(4.423)	(4.345)
0 km< distance reduction ≤ 1 km	0.467	6.597	-7.351
	(4.861)	(5.467)	(5.842)
0-km distance reduction	3.658	-3.232	12.51
	(7.224)	(7.078)	(7.569)
Post-treatment municipality–subway distance > 1 km			
1 km< distance reduction	2.161	4.066	-2.582
	(4.421)	(4.342)	(4.402)
0 km< distance reduction ≤ 1 km	1.579	0.598	2.156
	(5.125)	(5.039)	(5.735)
0 -km distance reduction (reference category)	0	0	0
	(0)	(0)	(0)
Observations	3,361	1,843	1,518
R-squared	0.267	0.319	0.287

Notes: As for Table 4.2. *** p<0.01, ** p<0.05, * p<0.1.

Table 4.7 Falsification check using data before the inauguration of new subway stations only: hours of work

Dependent variable: change in monthly hours of work 1996 to 2001	(1) All individuals	(2) Women	(3) Men
Post-treatment municipality–subway distance ≤ 1 km			
1 km< distance reduction	4.947	-9.463	20.88***
	(6.192)	(7.616)	(6.438)
0 km< distance reduction ≤ 1 km	8.616	16.86*	1.506
	(9.397)	(8.506)	(14.54)
0-km distance reduction	13.60	-13.78	45.69***
	(8.101)	(9.515)	(9.609)
Post-treatment municipality–subway distance > 1 km			
1 km< distance reduction	3.898	10.98	-7.281
	(6.201)	(7.751)	(6.607)
0 km< distance reduction ≤ 1 km	4.944	6.898	0.470
	(7.872)	(7.750)	(10.45)
0-km distance reduction (reference category)	0	0	0
	(0)	(0)	(0)
Observations	3,337	1,835	1,502
R-squared	0.200	0.263	0.197

Notes: As for Table 4.2. *** p<0.01, ** p<0.05, * p<0.1.

Table 4.8 shows the same falsification check in Tables 4.6 and 4.7 but using labour earnings as a dependent variable. The key coefficient in column (1) indicates that there was an increasing trend in individual labour earnings for treated individuals. On average, individuals in municipalities that would be treated in 2005 increased their earnings in US$89 per month (coefficient of 89.14) between 1996 and 2001.

Table 4.8 Falsification check using data before the inauguration of new subway stations only: individual labour earnings

Dependent variable: change in monthly individual labour earnings 1996 to 2001	(1) All individuals	(2) Women	(3) Men
Post-treatment municipality–subway distance ≤ 1 km			
1 km< distance reduction	89.14***	51.81***	152.1***
	(16.76)	(11.01)	(33.33)
0 km< distance reduction ≤ 1 km	65.14**	27.85	121.4**
	(27.88)	(17.86)	(55.25)
0-km distance reduction	36.05*	-8.918	105.6**
	(20.49)	(17.68)	(39.44)
Post-treatment municipality–subway distance > 1 km			
1 km< distance reduction	13.35	3.907	10.76
	(24.42)	(13.72)	(45.56)
0 km< distance reduction ≤ 1 km	22.86	5.066	51.65
	(20.64)	(12.30)	(38.12)
0-km distance reduction (reference category)	0	0	0
	(0)	(0)	(0)
Observations	3,306	1,820	1,486
R-squared	0.569	0.353	0.650

Notes: As for Table 4.2. *** p<0.01, ** p<0.05, * p<0.1.

Is the pre-treatment increasing trend in labour earnings of the treated group large enough to question the statistical significance of the conclusions from Table 4.3? One way to respond this would be to estimate a difference-in-difference-in-difference model subtracting the pre-treatment trend to the calculated effect in Table 4.3. The analysis underlying the generation of Table 4.9 implements this idea. Column (1) shows that the average effect of a large (more than one kilometre) increase in proximity to the subway network for workers in those municipalities that on average ended up closer than one kilometre from the subway network is still large in economic terms (US$119.5 per worker per month, a 39 per cent of the baseline salary of the treated group) but marginally significant (only at the 10 per cent of significance level). Hence, considering jointly the result in Tables 4.8 and 4.9, the positive effect of the treatment on individual labour earnings shown in Table 4.5 is not an extremely robust result.

Table 4.9 The effect of municipality–subway distance reduction on individual labour earnings: nonlinear difference-in-difference-in-difference models

Dependent variable: change in monthly individual labour earnings 2001 to 2006 minus 1996 to 2001 (in 2001 US$)	(1) All individuals	(2) Women	(3) Men
Post-treatment municipality–subway distance ≤ 1 km			
1 km< distance reduction	119.5*	-234.5***	498.9***
	(66.35)	(56.76)	(169.7)
0 km< distance reduction ≤ 1 km	-26.49	-53.07	-0.228
	(69.30)	(60.78)	(119.0)
0-km distance reduction	23.54	45.47	33.93
	(51.76)	(66.99)	(104.5)
Post-treatment municipality–subway distance > 1 km			
1 km< distance reduction	-100.1*	-63.80	-119.9
	(49.75)	(73.38)	(71.04)
0 km< distance reduction ≤ 1 km	18.66	-69.65	128.9*
	(43.82)	(61.42)	(66.61)
0-km distance reduction (reference category)	0	0	0
	(0)	(0)	(0)
Observations	2,413	1,346	1,067
R-squared	0.085	0.198	0.123

Notes: As for Table 4.2. *** p<0.01, ** p<0.05, * p<0.1.

To what extent where the characteristics of treated and control populations balanced in the year before the placebo experiment (1996)? Given that difference-in-difference methods assume parallel trends in the outcomes of treated and control populations (not equal cross-section outcomes) should the treatment would have not taken place, the answer to the previous question is not critical to the validity of my robustness check in this subsection. However, it is always illustrative to show a balancing test for the pre-placebo characteristics of treated and control populations. Table A9 in Appendix 9 shows that most covariates were balanced in 1996.

4.4.3.2 Using an unweighted sample

Are the results presented in section 4.4.2 robust to the omission of weights in the regressions? If the results using and omitting weights would be similar, this would decrease the concern about unobservables that could be correlated both with attrition and labour market outcomes. Table A8.1 and Table A8.2 in the Appendix show that the estimates of the effect of distance reduction to the subway network on women's employment status and hours of work using an unweighted sample are qualitatively similar to the effect using weights. This is, closer accessibility to the subway network implies an increase in the affected women's probability of employment and hours of work. However, Table A8.3 in the Appendix shows that the effect of closer proximity to the subway network on labour earnings for both men and women is negative (coefficients of USD 41.58 and 37.68 per month respectively). Hence, the effect on labour earnings in Table 4.5 is not robust to the omission of weights.

4.4.4 Why does the worker–subway distance matter?

An understanding of the economic story underlying the effects reported in this chapter is crucial. Table 4.10 shows that a large proportion (more than 70 per cent) of the increase in employment in treated women was in elementary occupations (such as domestic workers, manufacturing labourers and unskilled sales women). This provides suggestive evidence that the effect of the subway expansion on the employment rate was mainly on non-skilled women with a low income-generation capacity. This is consistent with the fact that skilled women may be less affected by a subway expansion relative to low-skilled women because the former may have other available modes of transport apart from public transport such as car.

Table 4.10 Occupations of treated female workers

Description	Totals per group		2006 minus 2001	Proportion of increased labour force
	2001	2006		
1. Professionals	0	1	1	14%
2. Technicians and associate professionals	1	1	0	0%
3. Clerical support workers	1	2	1	14%
4. Service and sale workers	4	3	-1	-
5. Skilled agricultural, forestry and fishery workers	0	0	0	0%
6. Craft and related trades workers	0	0	0	0%
7. Plant and machine operators and assemblers	0	0	0	0%
8. Elementary occupations	1	6	5	71%
Total	7	13	6	

Notes: The denominator of the proportion of the increased labour force is the sum of the non-negative changes in each category (i.e. excludes changes of employment status for service and sales workers).

4.5 Summary and conclusions

Better transport accessibility raises labour market participation rates, hours of work, and labour earnings. In the case of labour market participation, the effect is concentrated on women who perform elementary occupations such as domestic workers. This is consistent with an economic story where a decrease in transport costs is more likely to increase labour supply for those individuals with a higher 'transport-costs to reservation-wage' ratio. I use the panel data structure of my dataset to eliminate potential confounding effects that unmeasured characteristics of workers and common shocks to Santiago's employment rate could have had on my analysis. I show that a substantial improvement in labour market outcomes for individuals living in municipalities that ended up near to the subway network occurred after the explosive growth in the network during the mid-2000s. Moreover, during the period prior to the subway expansion (1996–2001), we do not observe the improvement effect observed in the period 2001–2006.

The results of this chapter are pertinent to the discussion about the relevance of commuting costs on labour market outcomes. To my knowledge, this is the first research that uses a convincing empirical strategy to conclude that better transport accessibility has a causal effect on labour market participation rates, working hours, and labour earnings.

This study may illuminate the evaluation of the impact of building public transport infrastructure on labour market outcomes. In future studies, data with individual addresses would be able to provide a more accurate measure of the effects discussed in this chapter because with such data the proximity to the subway network may be measured in an exact way.

My results suggest that further extensions in Santiago's subway network may further increase labour market participation rates, hours of work and labour earnings. Given that the Chilean government recently announced another major extension of Santiago's subway network (Latin Correspondent 2014), this will be a good opportunity to test furthermore the robustness of the results in this chapter.

Chapter 5

Better Urban Transport Implies Lower High School Test Scores

5.1 Introduction

High cognitive achievement is closely associated with outcomes such as higher future wages (Neal and Johnson 1996), higher schooling in childhood, marriage rates and not going on welfare (Herrnstein and Murray 2010). However, empirical evidence is not conclusive about the main factors affecting student achievement. Researchers have typically focused on traditional schooling inputs such as teaching quality (see, for example, Rockoff (2004)) or class size (Krueger and Whitmore 2001). Theoretically, better school accessibility could affect student supply because it decreases the student's generalised cost and effort to access certain schools. Because of spending less time and effort in commuting, if part of the additional time and effort is invested studying, students may improve their performance. In addition, better school accessibility could modify teacher supply (increasing it or decreasing it depending on whether initially most teachers live near or far from the specific schools). An increase (decrease) in teacher supply could increase (decrease) a school's value added by facilitating (making more difficult) the choice of high quality teachers by the school. Despite these links between school accessibility and student performance, little attention has been given to the effect of school accessibility on student outcomes.

Chile is an interesting place to study the effect of school accessibility on student outcomes for several reasons. First, more than 50 per cent of schools in Santiago experienced an increase in accessibility when a new 24-km subway line and six additional stations on an existing line were inaugurated in 2005. Such large and discrete change in school accessibility is currently unusual in OECD countries. Second, Chilean schools' institutional context enables school accessibility to have an effect on student outcomes through changes in school enrolment. Chile's educational system allows families to choose any school within their budget constraint (i.e. there are no catchment areas); in turn, changes in enrolment imply changes in schools' income given a government subsidy for public and private (voucher) schools which is proportional to the number of students attending the school.

Third, I have a detailed administrative individual panel dataset with students' test scores in Chile's national standardised test (SIMCE) one year before and one year after the inauguration of the new subway stations in Santiago. The panel nature of the dataset enables me to control for students' fixed characteristics and to avoid the contamination of my estimates with effects of changes in school composition due to better accessibility. I do this by considering as my treated population all students who attended treated schools during the pre-intervention period (regardless of whether they remained in treated schools after the transport innovation). This type of estimator has been called an intent-to-treat estimator (Little and Yau 1996).

To the best of my knowledge, there are no previous studies exploring the impact of school accessibility on student performance. On related topics, two studies have explored the impact of school accessibility (proxied by distance from school and commuting time) on post-compulsory education enrolment and graduation from upper-secondary schools. Using British data, Dickerson and McIntosh (2013), found that less distance between the students' homes and their closest school (measuring distance 'as the crow flies') is positively related to the probability that 'young people who are on the margin of participating in post-compulsory education (according to prior attainment and family background) continue into post-compulsory education' (Dickerson and McIntosh 2013, 742). This is consistent with Falch et al.'s (2013) finding, which concluded that reduced commuting time has a positive effect on graduation from upper secondary schools in Norway and that this effect is larger for students in the second and third quartiles of prior academic achievement.

These two papers have limitations. Dickerson and McIntosh's (2013) estimate of the impact of school accessibility on post-compulsory education enrolment may be biased upwards because of omitted variables such as household income. Falch et al.'s (2013) paper explores the impact of school accessibility on upper secondary school graduation, not on test scores as this chapter does. Test scores are of interest because they could signal the impact of school accessibility not only on students with low or median prior achievement but on the whole distribution of students.

Although there are no studies on the direct link between school accessibility and academic achievement, there is evidence about several potential mechanisms by which better school accessibility could affect test scores. Some of these mechanisms operate through changes in the value-added provided by schools. These mechanisms include increases in class sizes, increased competition between schools, increased school disruption due to higher pupil turnover, peer effects due to movers and stayers experiencing better or worse-performing peers, and teacher effects due to movements to schools with better or worse teachers. On the other hand, other mechanisms may affect student performance by channels not mediated by schools. These mechanisms include changes in neighbours' characteristics, increased truancy or changes in commuting time. In Chapter 1, I discuss each of these potential channels and their evidence. In the context of an intent-to-treat estimate, all these mechanisms are potentially relevant.

Several features in this chapter are useful when estimating the impact of school accessibility on student achievement. The first is the use of a convincing empirical strategy to show that student test scores respond to sizable improvements in school accessibility (proxied by school–subway network distance). To obtain a causal estimate I exploit the inauguration of new subway stations in Santiago in 2005 and argue that, conditional on a variety of controls for potential differential test score trends, the transport innovation is an exogenous shock to school accessibility.

This chapter's second feature is demonstrating the robustness of the conclusions. The analysis is as follows. I incorporate in my models a variety of student and spatial fixed-effects that account for test score differential trends. In addition, I explore not only the effect of linear school–subway network distance reduction (henceforth, distance reduction) but also the non-linear effects of the same variable by introducing distance reduction categories. Moreover, I am also able to distinguish the heterogeneous effects of school–subway network distance reduction depending on the distance from the new subway network. I also check that there is no evidence that unobservables are driving my results by carrying out a placebo test with a proposed line that had not yet been inaugurated in the post-expansion period (2006). Additionally, to avoid the assumption of no spatial correlation between the regression errors in my OLS time-differenced estimates I implement a permutation test on the school–subway network distance reduction category that is exact regardless of the presence of spatial correlation. Furthermore, in contrast to an important part of the literature that uses 'as the crow flies' distance (e.g. Dickerson and McIntosh (2013)), I measure school–subway station distances using walking distance. The latter is arguably a more accurate measurement of distance than the former because incorporates the shape and connectivity of streets in Santiago in the distance calculation.

A final feature of this chapter is that I establish my findings using administrative, individual panel data for all students in the same cohort rather than a cross-section of survey data. As stated before, the individual nature of the panel data enables me to calculate an intent-to-treat effect that avoids selection of students into treated or non-treated areas induced by the transport innovation. In addition, because I use data for the whole student population in Santiago, I am able to introduce detailed spatial controls (1 kilometre rings around the pre-treatment subway network, 42 municipalities in urban Santiago) that account for unobserved test score trends for small spatial units.

I find that school–subway network distance reductions of 4.7 km or more for students whose school ends up nearer than 2 km from the new subway stations worsen those students' scores by 11 per cent of a standard deviation. Conversely, on average, distance reductions of the same magnitude for schools at a 2 km distance or farther from the new subway stations have no effect on test scores. Moreover, on average, schools that experienced large distance reductions to the subway network also experienced an increase in their enrolled students.

The rest of the chapter is structured as follows. Section 5.2 explains my method when the outcome of interest is academic achievement. Hence, this section complements the generic explanation of my methods in Chapter 3. Section 5.3 describes the institutional context in education and data. Section 5.4 presents and discusses my results. Finally, Section 5.5 summarises this chapter and presents concluding remarks.

5.2 Method

5.2.1 Methodological framework applied to results on academic achievement

In this chapter, the fixed-effects model explained generically in Section 3.2 controls for unobserved characteristics of students such as the average ability of its students or skills of its teachers that could be correlated with both the changes in proximity to the subway network and changes in test scores before and after the subway expansion. In line with my preferred empirical specification depicted in equation (3.5), my main estimation equation in this chapter is:

$$(y_{i1} - y_{i0}) = \sum_j c_j\, h_{i1}\beta_{1j} + \sum_j c_j\,(1 - h_{i1})\beta_{2j} + x'_{i1}\gamma + (g_1 - g_0) + (\varepsilon_{i1} - \varepsilon_{i0}) \tag{5.1}$$

In (5.1), y_{it} is student i 's mathematics test score in period t; c_j are dummy variables, one for each of the four non-reference categories of distance reduction; $h_{i1} = I(d_{i1} \leq 2km)$, where $I(\ldots)$ equals one when the condition in the parenthesis is true and d_{i1} is the distance between student i´s school and its nearest subway station after the subway expansion; β_1 is the impact of better school accessibility on student test scores; x'_{i1} are baseline (pre-subway expansion) characteristics of students; g_t are shocks to test scores for all students in Santiago in year t, and ε_{it} is equation (1)'s error term. To uncover the impact of urban transport accessibility on student achievement, I work with mathematics test scores—rather than language ones—because the former are more susceptible to modification by school inputs (Chetty, Friedman, and Rockoff 2011).

5.2.2 Identification issues in the student fixed-effects model

As explained earlier, identification of the effect of better school accessibility on student performance rests on the assumption that there are no variables that are correlated both with students' test scores and with the 2005 school–subway network distance reduction. This assumption could be violated for five reasons. First, the identifying assumption would be violated if the shock (improvement) in school accessibility provided by the new subway stations induces selection into schools in the post-treatment period. This would happen if, for example, brighter students migrate more to or from treated schools because of increased accessibility to their schools and/or their places of residence. Second, as explained generically in Section 3.3, there may be a pre-existing test score trend where initially worse (better) performing students would improve differently from better (worse) performing students even in absence of the new subway stations. If the previous test score trend is correlated with the magnitude of the future school–subway network distance reduction this would bias my estimates.

Third, the assumption would also be violated if students in schools administered by different entities (municipality, municipal corporation, voucher or private entity) have differential average test score trends and the type of administration is correlated with the distance reduction magnitude. Fourth, the assumption would be violated if the mayors of certain municipalities could be better at lobbying to get the new subway lines to pass through their jurisdictions and these same mayors were pursuing educational policies that improved the quality of education and student achievement in schools in their jurisdiction. Fifth and finally, the identifying assumption would be violated if there were pre-existing spatial test score trends related to the school–subway network distance before the construction of the new subway stations. In the following paragraph, I address these identification issues.

With suitable data, I can address each of the five concerns about the internal validity of the fixed-effects estimates. The key idea is to control for test score differential trends. To deal with the first issue, the change in school accessibility inducing selection into schools, I estimate equation (5.1) calculating an intent-to-treat effect (Lachin 2000). I do this by considering that students are always attached to their pre-subway expansion school, regardless of their post-treatment actual school. This avoids selection into treated and non-treated schools due to the new subway lines and a potential resulting bias in the estimated effect of increased school accessibility. To deal with the second issue, a pre-existing test score trend that depends on the initial test score, I control for students' pre-intervention test scores in equation (5.1) to address pre-existing test score trends depending on students' initial scores. To deal with the third issue, I address pre-existing test score trends of students depending on their schools' type of administration by including in equation (5.1) the student's school type of administrative entity.

To deal with the fourth issue I address potential differential test score trends for students in schools in different municipalities by including municipality dummy variables in equation (5.1). There are 42 municipalities in urban Santiago, so I control for such potential differential trends by including 41 dummy variables, one for each (non-reference) municipality, in equation (5.1). In my preferred specifications (column (4) in Tables 5.2 and 5.3), I control for the interacted school-type-of-administration and municipality to control for test score differential trends for each type of administration in each municipality. To deal with the fifth identification issue, to address potential pre-existing differential test score trends for students in schools located at different distances from the old subway network, I include distance from the pre-intervention subway network in equation (5.1). A robust way to control for such trends is to do it non-parametrically in distance reduction by including one dummy variable for each kilometre of school–pre-treatment network distance.

In practice, the model that addresses the five identification issues exploits the relation between distance reduction and variation in students' test score progression only for students with similar initial test scores and the same administrative entity, in the same municipality, and within the same school-pre-intervention-subway-network distance band (one for each kilometre). Hence, the identifying assumption for the resulting model is that, controlling for test score trends along the five described variables, there are no omitted variables that are correlated with schools' average test scores and the 2005 distance reduction to the subway network.

5.3 Chile's institutional context in education and data

5.3.1 Chile's educational context

I provided background information about Chile's institutional context in education in Chapter 2. Since one relevant hypothesised channel for the impact of school accessibility on student achievement is through interactions between schools via changes in school enrolment or competition for teachers, it is also relevant to describe Chile's schools' funding mechanisms here. Municipal and voucher schools' budget constraints in Chile during the 2004-2006 period were mainly determined by the income from the student-per-capita per-day-subsidy. However, municipalities transferred resources from schools that were more profitable (generally larger schools with good pupil attendance) to less profitable ones. Moreover, municipalities were allowed to transfer resources from their general budget to their schools. Hence, the budget constraint was softer in municipal schools than in voucher schools.

5.3.2 Data

I use three main sources of data. First, Chile's SIMCE dataset contains an individual panel with test scores in eighth and tenth grades for students who were in eighth grade in 2004. Both in 2004 (for eighth graders) and in 2006 (for tenth graders), the SIMCE test was taken in November. This dataset contains language and mathematics test scores in both grades, as well as eighth grade social science and natural science test scores, and household income. SIMCE is Chile's standardized test that, during the period of study, was taken every year in fourth grade and some years in eighth or tenth grades.

Second, I then merged the SIMCE test information with the schools' georeferenced addresses and other administrative information such as the schools' type of administration (municipality, municipal corporation, voucher and private school). To obtain the schools' locations I normalised and geocoded the schools' addresses from Chile's Ministry of Education (publicly available) 2004 and 2006 archive. Third, I use the addresses of each subway station in Santiago. The pre-expansion subway network includes those stations that were inaugurated before the date of the baseline test (this is, on or before October 2004). The post-expansion subway network includes the pre-expansion subway network and all the subway stations inaugurated on or before the beginning of the academic year in 2006 (this is, between November 2004 and March 2006). Using Ozimek and Miles' (2011) *traveltime* command in Stata which connects to Google Maps, I found the walking distance between every school in Santiago and its nearest subway station.

Ideally, to offer a more comprehensive view of the effects of better transport accessibility on academic achievement, this study would have benefitted from having the individual addresses of the students. In Section 7.4, I reflect on the advantages that would imply having this type of data.

5.4 Results

5.4.1 Descriptive statistics

Summary statistics for schools in urban Santiago are shown in Table 5.1. The first two columns summarize the information about the zero school–subway-distance reduction subsample (the 'zero distance reduction' or 'untreated' sample), and the next two columns describe the positive school–subway-distance-reduction subsample ('positive distance reduction' or 'treated' subsample). The eighth grade pre-intervention average SIMCE score of students in schools in urban Santiago whose schools did not (did) experience a distance reduction was between 29–34 per cent (2–7 per cent) of a standard deviation above the national mean. In contrast, the average number of students in eighth grade in non-treated and treated schools is quite similar: 66.7 and 64.1 respectively.

Table 5.1 Descriptive statistics of schools in urban Santiago

	Zero distance reduction sub-sample		Positive distance reduction sub-sample	
	Mean	s.d.	Mean	s.d.
Number of schools	667		768	
Number of students	45,103		49,980	
Average standardised SIMCE 2004 scores				
Mathematics	33.6%	70%	6.6%	5.8%
Language	30.2%	60%	4.5%	5.2%
Social Science	28.9%	60%	2.4%	5.3%
Natural Science	29.3%	66%	3.9%	5.6%
Average number of students in same school and grade who took the SIMCE test in 2004.	66.7	62.9	64.1	43.7
Household median income (2004 US$)	421.0		252.1	
Type of Administration				
Municipal	19.7%		19.5%	
Municipal Corporation	15.7%		15.1%	
Voucher	46.5%		56.1%	
Private	18.1%		9.2%	
Minimum school–subway network distance in 2004 (km)	4.24		6.70	
Proportion of schools at a maximum distance of 2 km from the 2006 subway network	41%	49%	42%	49%
Distance reduction (km)	0		3.47	2.79
Categories of positive-distance-reduction schools				
0 km< distance reduction ≤ 1.6 km			25.5%	
1.6 km< distance reduction ≤ 2.3 km			27.9%	
2.3 km< distance reduction ≤ 4.7 km			22.3%	
4.7 km< distance reduction ≤ 10.7 km			24.3%	

Notes: The pre-intervention and post-intervention years are 2004 and 2006 respectively. Test scores are measured as z-scores standardised at the national level with a mean of zero and a standard deviation of one. Statistics are at the school level and (except for the 'students in same school' variable) are weighted by the number of students enrolled in 2004 who also took the SIMCE test in 2006. Zero (positive) distance reduction subsample refers to those schools who did not (did) experience a school–subway network distance reduction due to the subway stations inaugurated in 2005. The sample is restricted to those schools at a maximum distance of 20 km from the 2006 subway network with no missing values in all the described variables.

Monthly household median income is higher in the untreated subsample (US$421 per month) than in the treated subsample (US$252.1). Voucher schools represent a 9.6 percentage points higher proportion in the treated subsample compared to the untreated subsample. Conversely, private schools represent an 8.9 percentage point lower proportion in the untreated compared to the treated subsample. Hence, in terms of income and school type, students in the treated subsample are more vulnerable than in the untreated sample. This highlights the importance of controlling for differential test score trends for different socioeconomic groups and for type of school in my preferred specifications in Section 4.2. As expected, the average minimum school–subway network distance in 2004 was substantially lower for untreated schools compared to treated schools (4.2 km and 6.7 km respectively). The average distance reduction experienced by treated schools was 3.5 km.

5.4.2 Fixed-effects estimates

In this section, I analyse the impact of school accessibility on student outcomes using empirical specifications (3.2), (3.3), and (5.1) and accounting for identification issues in the ways discussed earlier.

Controlling for unobserved fixed student characteristics such as students' ability and families' socioeconomic status, better accessibility to schools is associated with worse student outcomes. Recall that in the empirical specification depicted in equation (3.2) I assume a linear and homogeneous effect of distance reduction on mathematics test scores regardless of the final school–subway distance. The coefficient on distance reduction in column (1) in Table 5.2 (–1.186) suggests that, for each kilometre of distance reduction to the subway network, students' average test score worsens by 1 per cent of a standard deviation. After accounting for differential test score trends depending on student pre-treatment characteristics (size of the student's school eighth grade, language, natural and social science SIMCE average score, income category of each household, and the student's school type of administration), the coefficient on distance reduction in column (2) in Table 5.2 (–1.201) does not change significantly in magnitude.

Table 5.2 The effect of school–subway distance reduction on mathematics test scores: linear model

Dependent variable: individual change in standardised test score 2004 to 2006	(1) Basic model	(2) As (1) plus school covariates	(3) As (2), plus heterogeneity in school-subway distance	(4) As (3), plus spatial controls
Distance reduction (km)	-1.186***	-1.201***		
	(0.163)	(0.162)		
Distance reduction (km) | distance ≤ 2 km			-1.186**	-1.341**
			(0.296)	(0.525)
Distance reduction (km) | distance > 2 km			-1.231**	-0.844
			(0.301)	(0.795)
Baseline characteristics				
Number of students in same school and grade in (log)	No	Yes	Yes	Yes
Language, natural and social science quintile	No	Yes	Yes	Yes
Household income	No	Yes	Yes	Yes
School type of administration	No	Yes	Yes	No
Municipality x School type of administration	No	No	No	Yes
Proximity to the old subway network	No	No	No	Yes
Observations	68,160	67,026	67,026	67,026
R-squared	0.002	0.018	0.018	0.032

Notes: The table reports regression coefficients and standard errors multiplied by 100 to give the % effect of a one-km change in distance reduction to the subway network. The dependent variable is post-treatment (2006, 10th grade) minus pre-treatment (2004, 8th grade) individual difference in standardised average language test scores; hence, this is a fixed-effects estimate. Test scores are measured as z-scores standardised at the national level with a mean of zero and a standard deviation of one. Regressions are run at the individual level. To get an intent-to-treat effect I assign students to their initial school even if the student changed school between initial and final periods. Distance reduction means distance reduction between the school and the nearest subway network because of the new stations between final and initial periods in kilometres. There are 15 categories of household median income; these categories are calculated obtaining the household median income in each school. Municipalities in the (urban) studied area are 42 and school type of administration categories are four (municipal, municipal corporation, voucher and private schools). Proximity to the old subway network is a set of 12 dummy variables; one for each km of school-subway distance (plus an omitted category). Robust standard errors in parentheses clustered at the Municipality level in all regressions. Sample restricted to schools at a maximum distance of 20 km from the new subway network. The largest distance reduction is 10.5 km. All regressions include an intercept (not shown). *** p<0.01, ** p<0.05, * p<0.1.

The estimates in columns (3) and (4) correspond to the model specified in equation (3.3). This specification allows for heterogeneous effects of distance reduction on test scores depending on whether the distance between the school and the post-treatment subway network is less-or-equal or more than 2 km. The coefficients on distance reduction in Column (3) in Table 5.2 for students in schools at a distance both smaller-or-equal and larger than 2 km are of the same magnitude and significance (–1.186 and –1.231 respectively). This suggests that the effect of distance reduction on mathematics test scores is homogeneous in school–subway post-treatment distance. However, once I add spatial controls (school administration types in each municipality and proximity to the pre-treatment subway network fixed effects), the distance reduction effect on mathematics test scores for students in schools that end up at a maximum distance of 2 km from the subway network (see column (4) in Table 5.2) increases in absolute terms to –1.3 per cent of a standard deviation per kilometre (coefficient equal to -1.341). By contrast, the distance reduction effect for students in schools that end up farther than 2 km from the subway network turns statistically insignificant (coefficient equal to –0.844).

When estimating equation (3.3) for obtaining the results in Table 5.2, I assume that the effect of the treatment (distance reduction) on test scores is linear; an alternative way to analyse the results is to allow for non-linear effects of distance reduction on test scores (still under a student-fixed-effects framework). Non-linearities can be introduced into equation (3.3) by using categories of distance reduction as treatment variables. I used five categories. Students in the first category are those whose school did not experience a distance reduction to the nearest subway station after the 2005 subway expansion (667 schools; 46 per cent of all schools). The other four categories are formed by dividing those schools that experienced a positive distance reduction into quartile groups. There are approximately 360 schools in each group. To be precise, the five categories of distance reduction are (1) null, (2) between 0.1 and 1.6 km inclusive, (3) between 1.6 and 2.3 km inclusive, (4) between 2.3 and 4.7 km inclusive, and (5) between 4.7 and 10.7 km.[11] In the regressions, the first category is the reference category.

Non-linear estimates suggest that the causal effect of a large school–subway distance reduction (larger than 4.7 km) for students in schools that ended up at a maximum distance of 2 km from the subway network is to worsen test scores in a policy-relevant way (see Table 5.3). The point estimates in column (1) show significant negative effects for the first (coefficient of –9.758), second (–7.461), and fourth (–4.952) distance reduction categories: a worsening between 5.0 and 9.6 per cent of a standard deviation compared to those students in schools that did not experience a distance reduction and were always farther than 2 km from the subway network). Controlling for pre-treatment student and students' school characteristics does not change the results in qualitative terms (see column (2) in Table 5.3)). (See Table 5.3's notes for a detail of these characteristics.)

[11] Google maps approximates distances to 100 m.

Table 5.3 The effect of school–subway distance reduction on mathematics test scores: nonlinear models

Dependent variable: individual change in standardised test score 2004 to 2006	(1) Basic model	(2) As (1) plus student covariates	(3) As (2), plus heterogeneity in school-subway distance	(4) As (3), plus spatial controls
4.7 km< distance reduction	-9.578***	-10.48***		
	(2.441)	(2.260)		
2.3 km< distance reduction ≤ 4.7 km	-7.461**	-7.959**		
	(3.252)	(3.101)		
1.6 km< distance reduction ≤ 2.3 km	-5.294*	-5.207*		
	(3.120)	(2.990)		
0 km< distance reduction ≤ 1.6 km	-4.952**	-4.929**		
	(2.332)	(2.106)		
0-km distance reduction (reference category for coefs. in columns (1) and (2))	0	0		
	(0)	(0)		
School-subway distance ≤ 2 km				
4.7 km< distance reduction			-12.08***	-11.14**
			(3.247)	(4.913)
2.3 km< distance reduction ≤ 4.7 km			-3.530	2.278
			(2.935)	(3.362)
1.6 km< distance reduction ≤ 2.3 km			-2.881	2.485
			(4.789)	(4.259)
0 km< distance reduction ≤ 1.6 km			0.000660	-2.339
			(2.843)	(3.363)
0-km distance reduction			2.099	-7.021
			(1.890)	(5.315)
School-subway distance > 2 km				
4.7 km< distance reduction			-5.997**	-2.428
			(2.531)	(3.142)
2.3 km< distance reduction ≤ 4.7 km			-12.10***	-5.988
			(3.628)	(5.675)
1.6 km< distance reduction ≤ 2.3 km			-4.838	-1.990
			(3.663)	(4.179)
0 km< distance reduction ≤ 1.6 km			-6.190**	3.046
			(2.319)	(2.278)
0-km distance reduction (reference category for coefs. in columns (3) and (4))			0	0
			(0)	(0)
Predetermined covariates (2004)				
Sex	No	Yes	Yes	Yes
Number of students in same school and grade (log)	No	Yes	Yes	Yes
Quintile group of baseline score in language, social science, and natural science	No	Yes	Yes	Yes
Household income	No	Yes	Yes	Yes
School type of administration	No	Yes	Yes	No
School has secondary school.	No	Yes	Yes	No
Municipality x Type of administration	No	No	No	Yes
Proximity to the old subway network	No	No	No	Yes
Observations	68,160	67,026	67,026	67,026
R-squared	0.003	0.021	0.022	0.034

Notes: As for Table 5.2. Distance reduction categories are five: one zero-distance reduction school (reference) category and four categories divided along quartiles of students in the non-zero distance reduction schools. *** p<0.01, ** p<0.05, * p<0.1.

As in Table 5.2, the specification in Table 5.3, column (3), allows for heterogeneity in the treatment effect. I allow such heterogeneity by interacting the distance reduction categories with the distance from the new subway stations. The size of the coefficient on the first category of distance reduction in column (3) is –12.08. The interpretation of this coefficient is the treatment effect for students in schools nearer than 2 km from the new subway stations that experienced a distance reduction larger than 4.7 km. Hence, controlling for all relevant covariates, test scores of students who before the inauguration of the new subway stations were in the latter group of schools worsened in 12.1 per cent of a standard deviation compared to students in schools that did not experience a distance reduction.

Table 5.3, column (4) shows my preferred estimates. Compared to column (3) these incorporate spatial controls: 42 dummy variables for municipalities and 12 dummy variables for each kilometre from the old subway network. The estimates in column (4) imply that the effect on test score of greater proximity to the subway network for students in schools that experienced more than 4.7 km of distance reduction and ended up nearer than 2 km from the new subway stations is –11 per cent of a standard deviation (coefficient of –11.14; see Table 5.3, column (4)). On average, students in schools that ended up farther than 2 km from the new subway stations and experienced large distance-to-the-subway-network reductions did not experience a significant change in their test scores after the inauguration of the new subway stations. Hence, the negative effect of better transport accessibility on test scores is driven by students in schools that ended up nearer than 2 km from the new subway stations. (All coefficients in the post-treatment school–subway distance greater than 2 km category are non-significantly different from zero.)

5.4.3 Robustness analysis

5.4.3.1 Robustness to a pre-existing test score trend at the municipal level

If there would be a pre-existing decreasing trend in treated students' test scores, this would bias my estimates. Because municipal schools are managed from within each municipality, the most likely pre-existing trend is at the municipal level. Since I am controlling for each municipality in the first differences specification depicted in equation 6.1, this controls for differential test score trends across municipalities. Hence, bias due to pre-existing differential test score trends should occur at an intra-municipality level. On the other hand, to test for the common test score trends assumption for test scores of treated and control students, I would need data for at least two periods before the subway expansion. Unfortunately, this data (for standardised tests) does not exist in Chile.

5.4.3.2 Robustness to a pre-existing test score trend correlated with future subway lines: placebo subway line

The common trends assumption would also be violated if an unobserved shock between the pre-subway expansion and post-subway expansion tests would affect the academic achievement of treated and control students in different magnitudes. For example, during 2006, secondary school students in Chile carried out the largest student demonstrations in Chile's last three decades (BBC News 2006). During 2006, almost 800,000 secondary students in Chile used strikes and demonstrations as a way of demanding a better quality of schools. The strikes, some of them lasting for months, may have had a significant effect on academic achievement. On the other hand, most of the new the new stations that opened in the mid-2000s were located along the main streets. Hence, if the proportion of students participating in strikes in a school correlated with the distance between the school and the nearest main street, the student strikes and demonstrations in 2006 could have biased my estimates.

A placebo experiment may falsify the previous concern. As I described in detail in Section 2.1.4 on Santiago's transport system, in 2001, a potential subway line to Maipú was competing with the line to Puente Alto for the central government's funding. Because the line to Maipú was not built at the time, I use it as a placebo subway line. Table 5.4 shows that the coefficients on all distance reduction categories are non-significant and extremely low in practical terms (all of them are smaller than five per cent of a standard deviation). Hence, there is no evidence that unobserved shocks like the student demonstrations affected treated students differently from control students and, thus, could be driving the significance of the results in my preferred specification (Table 5.3 column (4)).

Table 5.4 The effect of school–placebo subway distance reduction on mathematics test scores: nonlinear models

Dependent variable: individual change in standardised test score 2004 to 2006	
School–placebo distance ≤ 2 km	
4.7 km< distance reduction to placebo	0.179
	(3.742)
2.3 km< distance reduction to placebo ≤ 4.7 km	-0.700
	(3.615)
1.6 km< distance reduction to placebo ≤ 2.3 km	2.099
	(3.325)
0 km< distance reduction to placebo ≤ 1.6 km	2.222
	(4.668)
0-km distance reduction to placebo	-4.572
	(5.550)
School–placebo distance > 2 km	
0 km< distance reduction to placebo ≤ 1.6 km	-0.435
	(2.363)
1.6 km< distance reduction to placebo ≤ 2.3 km	-1.182
	(4.199)
2.3 km< distance reduction to placebo ≤ 4.7 km	-0.316
	(4.424)
4.7 km< distance reduction to placebo ≤ 10.7 km	2.921
	(3.330)
0-km distance reduction (reference category)	0
	(0)
Observations	61,993
R-squared	0.033

Notes and covariates: As for Table 5.3. In this table, 'placebo' stands for 'placebo subway network'. I exclude treated students from this sample. Treated students are those who experienced a distance reduction from the subway network larger than 4.7 km and ended up nearer than two km from the subway network.

5.4.3.3 Robustness to spatial correlation between the regression errors: permutation test

In this section, I also analyse the robustness of the results to different assumptions about spatial correlation between the students' test scores. In my preferred specification (Table 5.3, column (4)), I cluster standard errors at the municipality level. However, the regression errors could also be correlated across adjacent municipalities.

To consider the impact of spatial correlation between the regression errors I implement a permutation test of the treatment variable coefficient's standard error that is exact regardless of the presence of spatial correlation of the regression errors (and sample size). This tests derive from Fisher's (1935) exact test and have been further developed by researchers like Welch (1990) and applied by Abadie and Dermisi (2008). To implement such a test, I first produce 10,000 random permutations of the treatment variable (categories of distance reduction for column (4) in Table 5.3). Each permutation forces the null hypothesis—that the treatment is uncorrelated with the dependent variable—to be true by delinking the treatment and dependent variables. Second, I run the regression depicted in equation (4) with each permuted set of treatment variables. Third, I calculate the proportion of the permuted treatment variable coefficients that are greater in absolute value than the estimate calculated using the actual treatment ($\widehat{\beta_{1,5}}$). This proportion is a robust version of the p-value calculated under parametric assumptions in Table 5.3, column (4).

Only 1.3 per cent of the estimated coefficients are larger in absolute value than the ones in Table 5.3, column (4). This robust p-value is to be compared to the p-values implicit in column (4) in Table 5.3 obtained under parametric assumptions (1.5 per cent). Hence, regardless of the regression errors' spatial correlation, there is an extremely small probability of obtaining the results in my preferred specification (Table 5.3, column (4)) if the null hypothesis that there is no impact of better school accessibility on student test scores is true.

5.4.3.4 Robustness to a spurious correlation: use of language test scores

Despite the high statistical significance in the effect in column (4) of Table 5.3, it could be argued that the effect is only attributable to the natural variability in the data. If this were the case, we should not observe an effect of closer proximity between schools and the subway network when using another outcome variable. The specifications that generated Table 5.5 are identical to the ones that generated my preferred results (Table 5.3, which allows for non-linearities in the effect) but use language test scores as dependent variable. In Table 5.5, we also observe a significant effect of closer proximity between a school and the subway network. Even though the key coefficient in column (4) is significant only at the 10 per cent significance level (coefficient of –8.652), the decrease in statistical significance for the key coefficients in column (4) relative to the significance of the coefficient in column (3) (coefficient of –9.874) is mainly due to the increase in the standard errors when including spatial controls (not due to an a sharp decrease in the size of the coefficient).

Table 5.5 The effect of school-subway distance reduction on language test scores: nonlinear models

Dependent variable: 2006-2004 language average test score	(1) Basic model	(2) As (1) plus school covariates	(3) As (2), plus heterogeneity in school-subway distance	(4) As (3), plus spatial controls
4.7 km< distance reduction	-7.927***	-8.008***		
	(1.812)	(1.558)		
2.3 km< distance reduction ≤ 4.7 km	-3.303	-3.264		
	(2.072)	(1.986)		
1.6 km< distance reduction ≤ 2.3 km	-2.038	-2.958		
	(3.453)	(2.656)		
0 km< distance reduction ≤ 1.6 km	-1.354	-1.546		
	(2.165)	(1.697)		
0-km distance reduction (reference category for coefs. in columns (1) and (2))	0	0		
	(0)	(0)		
School-subway distance ≤ 2 km				
4.7 km< distance reduction			-9.874***	-8.652*
			(2.636)	(5.011)
2.3 km< distance reduction ≤ 4.7 km			-1.809	2.434
			(1.538)	(2.324)
1.6 km< distance reduction ≤ 2.3 km			-1.210	1.660
			(4.611)	(5.828)
0 km< distance reduction ≤ 1.6 km			-1.097	3.181
			(1.697)	(2.769)
0 km distance reduction			1.301	0.0894
			(1.736)	(3.579)
School-subway distance > 2 km				
4.7 km< distance reduction			-3.796**	-0.996
			(1.847)	(4.368)
2.3 km< distance reduction ≤ 4.7 km			-4.004	2.118
			(2.952)	(4.361)
1.6 km< distance reduction ≤ 2.3 km			-2.760	-0.465
			(3.243)	(2.845)
0 km< distance reduction ≤ 1.6 km			-0.916	3.807
			(2.148)	(2.319)
0 km distance reduction (reference category for coefs. in columns (3) and (4))			0	0
			(0)	(0)
Predetermined covariates				
Sex	No	Yes	Yes	Yes
Number of students in same school and grade in 2004 (log)	No	Yes	Yes	Yes
Quintile group of baseline score in language, social science, and natural science	No	Yes	Yes	Yes
Household income	No	Yes	Yes	Yes
School type of administration	No	Yes	Yes	No
School has secondary school.	No	Yes	Yes	No
Municipality x Type of administration	No	No	No	Yes
Proximity to the old subway network	No	No	No	Yes
Observations	68,031	67,115	67,115	67,115
R-squared	0.001	0.194	0.195	0.201

Notes: As for Table 5.3. *** p<0.01, ** p<0.05, * p<0.1.

5.4.4 Does the school–subway network distance really matter?

One way in which increased school accessibility could have had a non-causal impact on student outcomes is through changes in student dropout and repetition rates. This could have induced sample selection where worse performing students decreased their likelihood of dropping out from high school due to the accessibility improvement. My estimates in Section 5.4.2 are an intent-to-treat calculation where the students' post-treatment test scores are attached to their pre-treatment school. The new subway stations were inaugurated during the students' first year in high school (ninth grade). Hence, if better school accessibility increased the chance that students with worsening performance took the post-treatment (2006) test, this could induce a biased negative impact of distance reduction on individual test scores.

Table A5.1 in Appendix 5 shows that there is no evidence that distance reduction had an effect on the probability that a student who took the SIMCE test in 2004 would also take the test in 2006. Hence, there is no indication supporting the hypothesis that the negative effect of better accessibility on test scores was due to a decrease in dropout and repetition rates among the treated students. Therefore, I find no evidence of a non-causal explanation underlying my results.

5.4.5 Why does school–subway network distance matter?

The school–subway network distance reduction could affect student test scores through at least five mechanisms. First, schools that experienced large reductions in school–subway network distance could have received more students due to better accessibility after the inauguration of the subway stations compared to schools that did not experience such accessibility improvement. This, in turn, leads to an increase in the student–teacher ratio and to disruption for non-moving students in the treated schools. Both factors are associated with worse test scores. (See, for example, Krueger (1999) for the effect of smaller classes on student performance and Gibbons and Telhaj (2011) for the effect of pupil mobility and school disruption on test scores.)

Table 5.6 shows the effect of school–subway network distance reduction on the number of students per grade in each school. The dependent variable in Table 5.6 is the number of students in tenth grade in each school in the post-treatment period (2006) minus the number of students in tenth grade in the same school in a pre-treatment year (2003). I used 2003 as the pre-treatment year because this is the closest year before the inauguration of the subway stations in 2005 when students in tenth grade took the SIMCE test. As in all previous analyses, my preferred specification is depicted in column (4).

Table 5.6 The effect of school–subway distance reduction on the size of each school's cohort: nonlinear models

Dependent variable: students in each 10th grade cohort in each school in 2006 minus students in 2003	(1) Basic model	(2) As (1) plus school covariates	(3) As (2), plus heterogeneity in school–subway distance	(4) As (3), plus spatial controls
0-km distance reduction (ref. category)	0	0		
0 km< distance reduction ≤ 1.6 km	-13.81**	-14.47*		
	(5.404)	(6.523)		
1.6 km< distance reduction ≤ 2.3 km	-13.70	-14.36*		
	(8.819)	(6.640)		
2.3 km< distance reduction ≤ 4.7 km	0.621	-1.156		
	(4.100)	(1.682)		
4.7 km< distance reduction ≤ 10.7 km	9.450**	6.942**		
	(4.298)	(2.075)		
School–subway distance > 2 km				
0-km distance reduction (ref. category)			0	0
0 km< distance reduction ≤ 1.6 km			-17.57	-15.34*
			(9.946)	(8.552)
1.6 km< distance reduction ≤ 2.3 km			-15.27	-20.81
			(12.88)	(14.90)
2.3 km< distance reduction ≤ 4.7 km			4.777***	3.803
			(0.736)	(4.206)
4.7 km< distance reduction ≤ 10.7 km			5.103	4.959
			(2.456)	(5.814)
School–subway distance ≤ 2 km				
0-km distance reduction			1.503	2.444
			(4.814)	(9.123)
0 km< distance reduction ≤ 1.6 km			-9.769	-6.112
			(6.583)	(7.770)
1.6 km< distance reduction ≤ 2.3 km			-11.10	-6.382
			(5.781)	(5.349)
2.3 km< distance reduction ≤ 4.7 km			-5.233	-7.422
			(7.592)	(5.218)
4.7 km< distance reduction ≤ 10.7 km			9.998***	9.105**
			(1.010)	(3.886)
Quintile of number of students in same school and grade in 2003 fixed effects	No	Yes	Yes	Yes
Quintile of average school score in language and maths in 2003 fixed effects	No	Yes	Yes	Yes
School type of administration fixed effects	No	Yes	Yes	Yes
Proximity to the old subway network fixed effects	No	No	No	Yes
R-squared	0.030	0.240	0.245	0.257

Notes: As for Table 5.3. Regressions are run at the school level. *** p<0.01, ** p<0.05, *p<0.1.

Controlling for all relevant covariates, schools that experienced a large reduction in their distance from the subway network had an average increase of nine more students in tenth grade compared to schools that did not experience any distance reduction. Hence, there is evidence that one of the mechanisms through which the reduction in school–subway network distance affected test scores negatively is via an increase in the number of students per grade in the treated schools compared to the number of students per grade in the control group. In addition, this increase in the number of students per grade in the treated schools most likely implied disruption to the incumbent pupils in those schools.

A second mechanism through which a reduction in school–subway network distance could have affected test scores is through the effect of families choosing to change schools on achievement. Changing schools implies adaptation costs and, potentially, higher commuting times if the changes are to schools farther from the students' homes. Hanushek, Kain, and Rivkin (2004) conclude that the effect of families choosing to change schools on achievement is modest and negative (around 1 per cent of a standard deviation in terms of the annual gain in mathematics achievement).

I find no evidence that the school–subway network distance reduction experienced by some schools implied a higher probability that students in those schools would move to another school. Column (4) in Table A5.2 in Appendix 5 depicts the results of a regression of students' own movement (whether the student changed school after the inauguration of the subway stations) on distance reduction categories. In this regression, the coefficients on large distance reductions are not statistically significant and have a low absolute value in practical terms. Therefore, most likely, the negative impact of distance reduction on test scores is not driven by an increase in the probability that students in treated schools would change schools.

A third mechanism through which closer school–subway network proximity could have affected academic achievement is through changes in the parents' labour market outcomes. For example, lower labour earnings or more hours of work could have affected students' test scores negatively. Appendix 10 shows the main specification in Chapter 4 using the same distance threshold as in this Chapter (two kilometres). Using the distance threshold of two kilometres implies that the impact of school–subway network distance on employment status and hours of work (particularly women's) is positive but non-statistically significant (see column 2 in Tables A10.2 and A10.3). The policy or economic significance of these estimates is considerable (7 percentage points in employment status and 23 hours of work per week). On the other hand, on average, using a two-kilometre distance threshold implies that the effect of closer school–subway network proximity on labour earnings is negative, but not statistically significant.

Hence, changes in the labour market are potentially relevant mechanisms through which closer proximity to the subway network implied lower test scores. The fact that the size of the previously discussed coefficients is not statistically significant could be due to low power of my estimates due to a high spatial aggregation of the data in Chapter 4 (as described in section 4.3.1). Future work with individual addresses could improve the precision of these estimates.

A fourth mechanism through which closer proximity to the subway network could have affected test scores is through changes in peers experienced by treated individuals. Table 5.7 shows the change in the 2004 test score of each student's classmates between 2004 and 2006. This change in test scores is a proxy for whether the ability of each student's peers improved between 2004 and 2006[12]. Column (3) in Table 5.7 shows that this improvement is not statistically significant. Hence, there is no evidence supporting the hypothesis that peer effects were a relevant channel for the effect of the treatment. However, the caveat of this finding is that the fact of whether a student moved or stayed at their school during the 2004–2006 period could have been affected by the treatment status. The reason is that closer proximity to the subway network could have induced some students to move to another school, while inducing other students to remain at their primary school (due to fewer slots in some schools).[13]

Table 5.7 Descriptive statistics exploring peer effects channel

Dependent variable: change in the 2004 test score of students' classmates between 2004 and 2006	(1) Control students [s.d]	(2) Treated students [s.d.]	(3) Diff. (2)–(1) (s.e.)
Stayers	4.30	1.03	-3.27
	[13.03]	[18.63]	(3.17)
Movers	12.54	13.00	0.46
	[50.08]	[49.25]	(4.5)

Notes: The table reports regression coefficients and standard errors multiplied by 100 to give the % association in terms of standard deviations of Chile's SIMCE test. Sample constrained to the one in the main specification (Table 3, column 4). *** p<0.01, ** p<0.05, * p<0.1

A fifth mechanism through which closer proximity to the subway network could have affected academic achievement is through the effect of better or worse teachers. Unfortunately, to my knowledge, during the studied period there are no datasets with measures for teacher quality. An (imperfect) proxy for teacher quality could be the value-added provided by schools. Because

[12] The reason why I use pre-intervention (2004) test scores and not post-intervention ones is that the latter ones could be affected by the effect of closer proximity to the subway network.

[13] This possibility is compatible with the fact that, on average, the treatment did not increase the probability that a treated student would move to another school during the 2004–2006 period.

I want to avoid value added measures being contaminated by a potential effect of closer proximity to the subway network, I use the 'contextual average student performance' estimated with 2004 data in section 2.3.2 as a proxy for each school's value added. A problem of this measure is that it is only feasible to calculate for schools with eighth grade. Out of the 655 schools with students in the sample of my preferred specification (the one that generated Table 5.3, column (4)), it was not feasible to calculate the 'contextual average student performance' for a 22 per cent of these schools (145 schools).

Table 5.8 shows the change in the 2004 'contextual average student performance' for students who moved to another school between eighth and tenth grade. Column (3) shows that students in the control group experienced a greater increase in the proxy for their school's value added (coefficient of 12.35 percentage points of one standard deviation) relative to students in the treated group (coefficient of 4.57). However, this difference is not statistically significant at conventional levels. Hence, there is no conclusive evidence supporting the hypothesis that the effect of closer proximity to the subway network was due to treated students moving to worse schools relative to control students. As in the previous paragraph, a caveat for this conclusion is that whether a student moved to another school between 2004 and 2006 could have been affected by closer proximity between their school and the subway network.

Table 5.8 Descriptive statistics exploring teacher effects channel

Dependent variable: change in the 2004 "contextual average student performance" (proxy for value added) of the student's school between 2004 and 2006	(1) Control students [s.d]	(2) Treated students [s.d.]	(3) Diff. (2)–(1) (s.e.)
Movers	12.35	4.57	-7.78
	[51.13]	[53.57]	(5.1)

Notes: As for Table 5.6. . *** p<0.01, ** p<0.05, * p<0.1.

5.5 Summary and conclusions

The main purpose of this chapter is to establish whether improvements in school accessibility have a causal effect on student test scores. This is an important policy question because many developing countries are investing resources in improving their urban transport networks, though the consequences for human capital accumulation have often not been considered.

This chapter carefully addresses the identification of the impacts of better school accessibility on academic achievement. First, I use a detailed individual administrative test score dataset with information before and after the transport innovation, and thus avoid selection bias and changes in school composition by calculating an intent-to-treat effect. Second, I account for potential biases in my fixed effect estimates by controlling for test score differential trends in relevant dimensions. Third, I carry out robustness checks to unobserved differential shocks to treated and control student test scores and spatial correlation between the regression errors.

My main finding is that there is a large negative effect of school–subway distance reduction on test scores. Students in schools that experience a large decrease (of more than 4.7 km) in the distance from the nearest subway station, and ended up at a walking distance from the subway network, had average test scores that were lower by some 11 per cent of a standard deviation compared to test scores of students in schools that did not experience a distance reduction to the subway network.

The magnitude of this finding is large. In a review of 18 randomised evaluations reporting test score outcomes in developing countries, Kremer et al. (2013) reported that the upper bound of all 90 per cent confidence intervals of the average effect of educational programs was less than 9 per cent of a standard deviation.

I also find evidence that the negative effect of distance reduction on test scores is due to an increase in the number of students in schools that were now significantly closer to the subway network. Understanding the channels through which better school accessibility affects student performance is of key importance if policy makers wish to avoid undesired effects of new transport infrastructure on human capital accumulation.

Chapter 6

Better Urban Transport
Increases Robbery and Larceny in the Public Space

6.1 Introduction

Because of their effect on legitimate labour market outcomes and on accessibility to illegal activities, changes in transport connectivity may have a sizable impact on property crime rates at the neighbourhood level and, more generally, on the spatial distribution of crime within a city.

This chapter examines to which extent urban transport accessibility has an impact on property crime rates in areas near the transport improvements. In line with Becker (1968) and Ehrlich (1973), I assume that offenders, potential victims, and law enforcement authorities are rational individuals who interact in a 'market for offenses'. At an individual level, following Freeman (1999), an individual engages in crime if:

$$(1-p)U(W_c) - pU(S) > U(W) \tag{6.1}$$

where p is the probability of being apprehended, W_c is the monetary gain from committing an offence, S is the sanction for being apprehended, and W is the monetary gain from legal work.

In this framework, greater proximity to the subway network may affect the supply of crime by affecting different variables in equation (6.1). First, greater proximity to the subway network lowers the (generalised) cost of access of the area to potential offenders. In those types of crime where the offenders might use the subway to reach their targets (such as robbery and thefts), the decrease in the cost of transport increases W_c, the net payoff of these property crimes. This, in turn, increases property crime in that specific area.

Second, as seen in Chapter 4, greater proximity to the subway network increases W, the affected workers' labour earnings from legal activities. This has at least two consequences. On the one hand, in the medium and long term, an increase in labour earnings of potential victims increases their wealth. This increases the attractiveness of these potential victims as targets of crime, raising W_c. An increase in the payoff of property crime increases the amount of property crime. At the same time, an increase in the potential victims' wealth increases their payoff and willingness to pay for private security measures like burglar alarm systems or safety deposit boxes (Bennett and Wright 1984; Skogan and Maxfield 1981). An increase in security measures decreases property crime either by increasing the probability of apprehension p or by decreasing the payoff from an attempt of a property crime offence. On the other hand, if, as concluded by Brantingham and Brantigham (1984), offenders act locally, an increase in their expected labour earnings from legal activities (W) increases the opportunity cost of engaging in criminal activities; this decreases the amount of property crime.

Third, when an area increases its proximity to the subway network due to better urban transport accessibility, the area becomes a more attractive place to live in. Proof of this greater attractiveness is the well-established fact that greater proximity to the subway network implies higher property prices (see, for example, Gibbons and Machin 2005). This, in turn, attracts wealthier citizens to the area with improved transport access (Pagliara and Papa 2011). Following the same logic as in the previous point, a greater wealth of residents might imply either an increase or decrease in the equilibrium quantity of property crime in the area. Fourth, a greater proximity to the subway network implies a greater flow of pedestrians (Miranda-Moreno, Morency, and El-Geneidy 2011). This has at least two implications. On the one hand, using Jacobs' (1961) language, a greater flow of pedestrians implies that there are more 'eyes on the street', which, in turn, may increase the probability that an ongoing criminal act is denounced to the police. This implies an increase in the probability that the police catch the offender, p. This, in turn, reduces the equilibrium amount of property crime. On the other hand, a greater flow of pedestrians implies that the concentration of potential targets of crime increases. This, in turn, decreases the effort exercised by a criminal in finding a profitable victim. This increases the payoffs from property crime in the area (W_c), increasing the (short-term) equilibrium quantity of property crime to pedestrians such as robbery and larceny. Fifth, greater proximity to the subway network may also increase the frequency at which the police patrol the surroundings of the new subway stations (TriMet 2013). This increases the probability of burglars, robbers, and thieves being caught (p), making these places less attractive to them. This, in turn, decreases the equilibrium quantity of crime.

Considering all these potential effects of greater proximity to the subway network on the amount of property crime, the different types of property crimes (burglary, robbery, or larceny) could increase, remain at the same level, or decrease. Hence, the question that motivates this study is an empirical one.

Some studies have explored the effects of subway lines on the spatial distribution of crime. Block and Davis (1996), using data from Chicago, find that crime rates in low-crime districts are highest at 300 m distance from subway stations. The researchers explain their finding arguing that this distance is far enough from the station security personnel, but still close enough that the density of commuters is not too low.

Using data from Atlanta in the USA, Poister (1996) concludes that reported crime increased after a rapid rail station opening in 1993. However, after several months, crime returned to its earlier levels. One problem with this study is that there is no control group for the area surrounding the station; hence, the observed increase and decrease in reported crime rate may just have a spurious relation with the station opening.

Liggett et al. (2003) conclude that the inauguration of a light rail line in Los Angeles did not increase (and in some cases decreased) crime rates in the relatively poor neighbourhoods near the new rail stations. Moreover, they also conclude that the line did not increase crime in more affluent neighbourhoods that, being already close to the light rail before its expansion, feared an increase in crime due to the line opening. One limitation of this study is that it uses the crime rate in the county of the new rail stations as a counterfactual to the crime rate in the neighbourhood near the new rail stations. Because in absence of the new rail line, the crime rates in the station's county and in the station's vicinity could have been different. In this study, the difference-in-differences common trends assumption does not necessarily hold.

In the research most closely related to the present study, Billings et al. (2011) find that the announcement of a light rail line in 2007 in Charlotte (North Carolina) decreased robbery, burglary and larceny in the neighbourhoods around the new train stations by 32.4 per cent, 26.3 per cent and 25 per cent respectively, relative to control neighbourhoods. Hence, crimes to both moving (robbery and larceny) and non-moving targets (burglary) decreased after the announcement of a light rail line in Charlotte. In this study, Billings et al. (2011) control for unobserved neighbourhood fixed effects using panel data and use neighbourhoods around alternative corridors that were not built as a control group.

The main contribution of the present chapter is to use a convincing empirical strategy to estimate the effect of greater proximity to the subway network on the spatial distribution of property crime rates. To control for pre-existing crime trends across municipalities I control for each municipality in the first-differences regressions. In addition, I check that there is no evidence of unobservables such as a potential differential increase in mobile phone (a target of crime) use in treated and control areas that could be biasing my results. Second, this chapter uses georeferenced data for every crime reported to the police in Santiago in 2005 and 2007, the years before and after the expansion of the subway network in Santiago. To my knowledge, this is the first study in a developing country context using this level of detail in the data. Third, the treatment variable in this chapter is the distance reduction to the subway network experienced by each crime area in Santiago. All previous research use distance bands around the new subway stations as treatment variables. This approach does not acknowledge the fact that the intensity of the treatment varies for locations that end up near the subway network but experience different distance reductions to the subway network.

I define treated areas to be those that became more than two kilometres nearer to the subway network and ended up at a walking distance from it (this is, less than two kilometres) due to Santiago's subway expansion in the mid-2000s. I define the control areas to be those that were farther than two kilometres from the subway network before the subway expansion and did not experience any distance reduction to the subway network in the mid-2000s.

I find that, on average, robbery and larceny in treated areas increased by 18 per cent and 43 per cent respectively after the inauguration of the new subway stations relative to the change in the same type of crime experienced by the control areas. By contrast, burglary did not change differently in treated and control areas.

There are no theoretical reasons why greater proximity to the subway network should have a linear effect on property crime rates. Previous studies using other outcome variables have identified that there is an effect insofar the affected location ends up at a maximum threshold distance from the subway network. While Gibbons and Machin (2005) and Ahlfeldt (2013) found that this threshold for the effect of greater proximity to the subway network on property prices was two kilometres, in Chapters 4 and 5 I find that this threshold is two and one kilometres respectively. Hence, I expect that there could be a heterogeneous effect of distance reduction to the subway network on property crime rates depending on the distance from the subway network after the subway expansion.

The rest of this chapter is structured as follows. In Section 6.2, I describe the application of the generic estimation equation 3.5 derived in Chapter 3 to the particular case when the outcome of interest are different types of property crime. In Section 6.3, I describe the data. Section 6.4 describes the descriptive statistics, main results and robustness analysis. Finally, Section 6.5 provides conclusions to this chapter.

6.2 Method

To study the effect of proximity to the subway network on property crime rates, I use a fixed-effects model using crime areas as unit of observation. To simplify the notation, I now show the specification for just one type of crime (for example, burglary). In line with the general case outlined in specification (3.5), my estimation equation is

$$(y_{i1} - y_{i0}) = \sum_j c_j\, h_{i1}\beta_{1j} + \sum_j c_j\,(1 - h_{i1})\beta_{2j} + x'_{i0}\gamma + (g_1 - g_0) + (\varepsilon_{i1} - \varepsilon_{i0}) \tag{6.1}$$

where y_{it} is the property crime rate for crime area i at time t; c_j are dummy variables, one for each of the three categories of distance reduction (0 km, 0 km< distance reduction ≤ 2 km and Distance reduction > 2 km); $h_{it} = I(d_{it} \leq 2\ km)$, where $I(\ldots)$ equals one when the condition in the parenthesis is true and zero otherwise; β_{1j} is the effect of proximity to the subway network on crime outcomes; x'_{i0} is a vector that contains area i's baseline characteristics such as the baseline year's property crime rates (excluding the dependent variable's specific category of property crime) and average distance from the subway network before the network's expansion; g_t are general time effects that account for changes to the property crime rate during a specific year in the whole city; and ε_{it} is equation (6.1)'s error term.

6.3 Data

I use data on all crimes reported to the police in Santiago in the pre-intervention and post-intervention years (2005 and 2007 respectively). A crucial strength of police-recorded crime is that the police record the location of each of the reported offenses. This is the case in my dataset. Another strength of police-recorded crime is that it provides a lengthy time-series dataset.

One weakness of police-recorded crime is that counting rules—such as how to count repeated offenses within a short period—may change (Maguire 2012). This may be due to changes in the official way to aggregate offenses (Maguire 2012). An additional weakness of police-recorded crime is that the criteria with which the police define which crimes to record are subject to a certain degree of discretion, and the way the police exercise this discretion may change over time (Maguire 2012). Another weakness of police-recorded crime is that the official 'list' of offenses may change (Maguire 2012). To my knowledge, between 2005 and 2007, Chile's police did not change any of the rules for counting or recording crime, the way in which the police exercised discretion on which crimes to record, or in the official list of offenses. Finally, the willingness of the public to report crime may change in time (Maguire 2012). In Section 6.4.4, I test whether my results are robust to changes in the public's willingness to report crime.

A second source of data on crime widely used nowadays is victimisation surveys. One advantage of these surveys is that they count incidents not reported to the police and that they are not subject to changes in counting rules, official lists of crime, or the way the polices exercises discretion in counting procedures. Chile's main victimisation survey is the '*Encuesta Nacional Urbana de Seguridad Ciudadana*' ('National Survey of Urban Public Safety' or 'ENUSC' in Spanish). For my research, the main disadvantage of the ENUSC is that, due to confidentiality issues, I was not allowed access to the addresses of the respondents. In addition, these kinds of surveys would generally not record the address where the robbery and thefts suffered by the respondents occurred.

The police recorded each reported crime and Chile's Undersecretary of Crime Prevention *('Subsecretaría de Prevención del Crimen'*) georeferenced the dataset. As a way to check the accuracy of the georeferencing process, I checked whether all georeferenced crimes were located within the limits of Santiago's urban area (see Appendix 7 for this definition). All georeferenced crimes passed this test.

In this chapter, the unit of analysis is a crime area. These are small spatial units with an average surface of one hectare. Chile's Undersecretary of Crime Prevention uses crime areas as an administrative territorial division to monitor the crime levels in each locality in Chile. In Chile's Metropolitan Region of Santiago ('Santiago'), there are 8,022 crime areas with data in 2005 and 2007. On average, there are approximately 200 crime areas per municipality in Santiago. To get the average distance between any specific crime area and the 2005 and 2007 subway networks, I used the average distance from the nearest subway station of all crimes in a crime area in 2005 to the subway networks in 2005 and 2007 respectively. For specific details about the construction of the different crime categories, see Appendix 6.

6.4 Results

6.4.1 Descriptive statistics

Table 6.1 reports summary statistics on crime rates and distance reduction to the subway network in Santiago. While 13 per cent of crime areas are treated areas, 35 per cent are control areas. Hence, a 52 per cent of crime areas are neither treated or control areas. Treated areas are those that experienced a significant distance reduction to the subway network in the mid-2000s (greater than two kilometres) and ended up at a 'walking distance' from the new subway stations (two kilometres or less). The threshold of two kilometres as a walking distance is the one that, using intervals of 500 metres, maximises the R-squared of the regression in column (1) of Table 6.2. The use of a walking distance to allow heterogeneity in the effect of proximity to the subway network on property crime rates is important because we should expect that all the potential mechanisms discussed in Section 6.1 should apply to areas that end up at a walking distance from the subway network. There is no theoretical reason to suppose that the potential channels discussed in Section 6.1 should apply to those areas that end up farther away than walking distance from the subway network. In addition, this threshold is the same as the walking distance used in Gibbons and Machin (2005) and in Chapter 5 of this thesis. On the other hand, control areas are those who did not experience any distance reduction to the subway network and were always farther away than two kilometres from the subway network. In 2005, both treated and control areas were at almost the same average distance from the subway network (5.6 km). In 2007, due to the expansion of the subway network, the average distance from the subway network of treated crime areas decreased sharply to one kilometre.

Table 6.1 Summary statistics on crime rates and distance reduction to the subway network in Santiago

	(1) All areas in Santiago [s.d]	(2) Treated areas [s.d]	(3) Control areas [s.d]	(4) Diff. (2)–(3) (s.e.)
Share of each group out of all crime areas	1.00	0.13	0.35	
Categories of distance reduction				
Distance reduction > 2 km	0.23	1	0	
	[0.42]	[0]	[0]	
0 km< distance reduction ≤ 2 km	0.18	0	0	
	[0.38]	[0]	[0]	
0 km distance reduction	0.59	0	1	
	[0.49]	[0]	[0]	
Municipality–subway distance (km)				
2005	4.34	5.61	5.59	0.02
	[3.12]	[2.49]	[2.75]	(0.09)
2007	3.16	0.99	5.59	-4.60***
	[2.79]	[0.51]	[2.75]	(0.05)
Robbery in the public space				
2005	6.09	5.37	4.38	0.99***
	[9.46]	[7.23]	[6.75]	(0.26)
2007	6.34	5.69	4.24	1.46***
	[11.2]	[9.26]	[7.44]	(0.32)
Larceny in the public space				
2005	0.73	0.52	0.41	0.11**
	[3.02]	[1.17]	[1.16]	(0.04)
2007	0.54	0.39	0.28	0.11***
	[2.5]	[1.26]	[1.05]	(0.04)
Burglary				
2005	3.01	3.64	2.72	0.92***
	[2.91]	[2.83]	[2.84]	(0.10)
2007	2.44	2.75	2.05	0.70***
	[2.43]	[2.32]	[2.12]	(0.08)
Domestic violence				
2005	3.98	4.60	4.08	0.52***
	[4.91]	[4.42]	[5.63]	(0.17)
2007	3.37	3.76	3.33	0.44***
	[3.86]	[3.5]	[4.17]	(0.13)
Number of crime areas in each subgroup	8,022	1,061	2,819	3,880

Notes: Columns (1) to (3) report sample means with standard deviations in brackets. Column (4) reports the difference between columns (2) and (3) with standard errors in parentheses. There are 8,022 crime areas in Santiago with data in both periods (2005 and 2007). Distance reduction means average distance reduction between every crime in 2005 (year before the subway network expansion) in each crime area and the nearest subway network because of the new stations between final and initial periods. The largest distance reduction is 10.5 km. Treated crime areas experienced a distance reduction to the subway network greater than two kilometres and ended up nearer than two kilometres on average from the subway network in 2005. Control crime areas did not experience a distance reduction to the subway network in 2005 and in both periods were farther than two kilometres from the subway network. See glossary of terms for the definition of burglary, robbery, theft, domestic violence and violence in the public space. The sample includes all crimes in the Santiago metropolitan urban area (see Appendix 7 for limits). *** p<0.01, ** p<0.05, * p<0.1.

Table 6.1 also shows that in 2005 there were more property crimes in treated than in control areas. In 2005, on average, there were 0.99 more robbery in treated than in control areas; in

2007, this difference increased to an average of 1.46 more robbery per crime area per year. By contrast, both in 2005 and 2007, treated areas had 0.11 more larcenies per area per year relative to control areas. In addition, in 2005 treated areas had 0.92 more burglary per area per year relative to control areas. However, in 2007 this difference decreased to 0.70 more burglary per area per year relative to control areas. Finally, in 2005, treated areas had 0.52 more reports of domestic violence relative to control areas. Even though the level of domestic violence decreased in 2007, treated areas still had 0.44 more reports of domestic violence relative to control areas.

These differences suggest that the opening of the new subway stations in the mid-2000s in Santiago led to a reduction in burglary and domestic violence and an increase in robbery in treated relative to control crime areas. However, are these differences substantive? Could non-observed (by the econometrician) characteristics of the treated areas such as the municipal mayor's lobbying capacity have affected both the location of the new subway stations and the fight against crime relative to control areas? Similarly, could previously existing spatial trends be driving the differences seen in Table 6.1? I explore these questions in the next section.

6.4.2 Main results

My main results follow equation (6.1) that is my preferred empirical specification. To account for unobserved fixed characteristics of the crime areas such as the local mayor's capacity to lobby for the subway to pass by her municipality and lobbying the police to be more effective in her municipality, I use crime-area fixed-effects models. Table 6.2 shows the results of my preferred specification. In this specification, I allow for heterogeneity in the effect of greater proximity to the subway network on property crime rates depending on whether the area ended up at a walking distance from the nearest subway station. In addition, I allow for non-linearities in the previous effect. Controlling for the municipality of each crime area, the pre-expansion proximity to the subway network and central business district, and the pre-subway expansion levels of property and violent crime, robbery and larceny in the public space increase in treated relative to control crime areas. The effect on the treated areas is 0.97 (coefficient of 0.966) more robbery per area per year (see column (1)). This represents an increase in 18 per cent of robbery with respect to the 2005 level of robbery in treated areas.

Table 6.2 The effect of crime area–subway distance reduction on crime rates: nonlinear models allowing for heterogeneity in walking distance

Dependent variable: change in number of crimes per crime area 2005 to 2007	(1) Robbery in the public space	(2) Larceny in the public space	(3) Burglary	(4) Domestic violence
Post-treatment municipality–subway distance ≤2 km				
Distance reduction > 2 km	0.966**	0.226***	-0.228	0.226
	(0.463)	(0.0815)	(0.189)	(0.353)
0 km< distance reduction ≤ 2 km	0.271	0.145*	-0.288	-0.0897
	(0.604)	(0.0738)	(0.186)	(0.225)
0-km distance reduction	-0.471	-0.0215	-0.219	-0.200
	(0.296)	(0.0670)	(0.159)	(0.219)
Post-treatment municipality–subway distance > 2 km				
Distance reduction > 2 km	0.769*	0.136	0.0905	0.274
	(0.447)	(0.0929)	(0.206)	(0.639)
0 km< distance reduction ≤ 2 km	0.633	0.146*	0.150	-0.157
	(0.452)	(0.0842)	(0.172)	(0.257)
0-km distance reduction (ref. cat.)	0	0	0	0
	(0)	(0)	(0)	(0)
R-squared	0.163	0.129	0.082	0.180

Notes: The coefficient in each row represents the change in the number of crimes per crime area between 2005 and 2007 relative to the control areas. The control areas did not experience a distance reduction to the subway network between 2005 and 2007 and in both periods were farther than walking distance (two kilometres) from the subway network. The dependent variable is the number of crimes per area reported to the police in the post-treatment (2007) minus the same number in the pre-treatment (2005) periods. The sample includes all crimes in the Santiago metropolitan urban area (see Appendix 7 for its definition). Regressions are run at the crime area level. There are 8,022 crime areas with observations in both periods in Santiago. Distance reduction means average distance reduction between every crime in 2005 in each crime area and the nearest subway network because of the new stations between final and initial periods. All regressions control for the linear and quadratic pre-treatment levels of robbery in the public space, larceny in the public space, burglary, injuries and violence in the public space and domestic violence, excluding the regressor of the same category as the dependent variable in each column. At a spatial level, these regressions control for proximity to the pre-intervention subway network and proximity to the central business district (located in Plaza Baquedano). Proximity to the pre-intervention subway network is implemented through a set of 12 dummy variables, one for each km of crime area–subway distance (plus an omitted category). Proximity to the central business district enters in the regression through its linear and quadratic terms. Robust standard errors clustered at the municipality level in parentheses. All regressions include an intercept (not shown). The largest distance reduction is 10.5 km. *** p<0.01, ** p<0.05, * p<0.1.

In addition, the effect of closer proximity to the subway network on treated areas is 0.23 (coefficient of 0.226) more larceny in the public space per crime area per year (see column (2)). This is a 43 per cent increase in larceny with respect to the 2005 level of larceny in treated areas. On the other hand, closer proximity to the subway network had a negative but non-statistically significant effect on the yearly rate of burglary (see column (3)). Similarly, closer proximity to the subway network had a positive but non-statistically significant effect on the yearly rate of domestic violence (see column (4). As expected theoretically, the crime rates in areas that experienced large distance reductions to the subway network (more than two kilometres) but ended up farther than two kilometres from the subway network, did not change significantly relative to the property crime rates in the control areas. To avoid bias due to serial autocorrelation (see Nickell (1981)), in all regressions specified by equation 6.1 (whose coefficients are displayed in Table 6.2), I exclude the baseline covariate crime category of the dependent variable. However, the inclusion of this crime category does not have any impact on my findings (results not shown, available on request).

To simplify the analysis, in Table 6.3, I assume a linear relation between proximity to the subway network and the amount of property crime. Hence, the treatment variable in this specification is distance reduction to the subway network. In a similar fashion to the specification used in Table 6.2, the specification in Table 6.3 allows for heterogeneity in the effect of the treatment for those crime areas that ended up closer and farther than two kilometres from the subway network. The results in Table 6.3 are consistent with the ones in Table 6.2.

The coefficient on the interaction between distance reduction to the subway network and ending up at a post-treatment walking distance from the subway network (less than two kilometres) in 0's column (1) indicates that, after controlling for all covariates already mentioned in 0, an additional kilometre of proximity to the subway network is associated with a 0.26 (coefficient of 0.255) increase in the number of robbery per crime area per year. This is an increase of 4.7 percentage points in the number of robbery in the public space in 2005 per kilometre of proximity to the subway network. In addition, the coefficient on Table 6.3, column (2)'s interaction between distance reduction to the subway network and ending up at a post-treatment walking distance from the subway network indicates that an additional kilometre of proximity to the subway network is associated with a 0.03 (coefficient of 0.0335) increase in larceny per crime area per year. This represents an increase of 6.4 percentage points in the number of larceny in the public space in 2005 per kilometre of closer proximity to the subway network. By contrast, column (3) (column (4)) shows that an additional kilometre of proximity to the subway network is associated with a non-statistically significant decrease (increase) in burglary. In addition, as expected, the coefficients on the interaction between distance reduction to the subway network and ending up farther than a walking distance from the subway network in columns (2) and (3) are small in economic terms and not significant. The fact that the coefficient in column (1) is significant (coefficient of 0.232) suggests that closer proximity to the subway network could have a positive effect on robbery even beyond the two-kilometre cut-off.

Table 6.3 The effect of crime area–subway distance reduction on crime rates: linear models allowing for heterogeneity in walking distance

	(1)	(2)	(3)	(4)
Dependent variable: change in number of crimes per crime area 2005 to 2007	Robbery in the public space	Larceny in the public space	Burglary	Domestic violence
Distance reduction (km) | distance ≤ 2 km	0.255***	0.0335*	-0.0193	0.0578
	(0.0793)	(0.0189)	(0.0404)	(0.0999)
Distance reduction (km) | distance > 2 km	0.232**	0.0245	0.0119	0.0150
	(0.0927)	(0.0234)	(0.0505)	(0.173)
R-squared	0.163	0.128	0.081	0.179

Notes: As for Table 6.2. *** p<0.01, ** p<0.05, * p<0.1.

6.4.3 Robustness analysis

One potential concern about the validity of my estimates is that an increasing trend in robbery and/or larceny prior to the subway expansion could be biasing my estimates. As mentioned earlier, if a specific mayor would have been good at lobbying for the subway to pass through the municipality and at implementing changes that could decrease crime (such as improving street lighting), this could bias the previous estimates. Because I am introducing in all my first-differences specifications a dummy for each municipality, the 'active mayor' as a cause for bias is controlled for.

Another potential threat to identification would be citywide shocks that could have a differential effect on the crime rates of places more prone to be benefitted with new subway stations because of unobserved (to the econometrician) characteristics. For example, during 2005 and 2007, the usage of mobile phones in Chile increased almost 20 percentage points (Ministerio de Economía, Gobierno de Chile 2009). In addition, Harrington and Mayhew (2001) report alarmingly high figures of mobile phone robbery and larceny. If individuals who became users of a mobile phone during the 2005–2007 period were more likely to transit through places more prone to be benefitted by future subway lines, this could be biasing upwards the calculated impact of closer proximity to the subway network on robbery or larceny. To check that my estimates are not prone to this type of bias, I run a placebo experiment. The placebo subway line should also be in Santiago and its citizens or crime areas should share similar characteristics in terms of the likelihood of being a victim of crime of treated citizens.

As explained in Section 2.1.4 on Santiago's transport system, my placebo experiment consists of running the analysis depicted by equation (6.1), but using a subway line with similar characteristics to the subway lines of the expansion in the mid-2000s. The placebo line must not have been built during the post-expansion period (2007). In an analysis of the effect of railway lines on development in Ghana, Jedwab and Moradi (2011) also use train lines not yet built at the time of the data collection as a placebo experiment to test for unobservables that could be driving their results. If there are no unobservables driving my results, we should also expect that the effect of the placebo experiment should be non-significant both in statistical and practical terms. Under no omitted variable bias, I expect a non-significant association between closer proximity to the potential subway network and the crime areas in the placebo experiment because we would be analysing the effect of a potential subway expansion that did not occur by the time of the data collection. Table 6.4 shows that the association between accessibility and property crime rates in the placebo experiment is non-significant.

Table 6.4 The effect of distance reduction to a placebo subway line on property crime rates: nonlinear models allowing for heterogeneity in walking distance

Dependent variable: change in number of crimes per crime area 2005 to 2007	(1) Robbery in the public space	(2) Larceny in the public space	(3) Burglary	(4) Domestic violence
Post-treatment municipality–subway distance ≤2 km				
Distance reduction > 2 km	-0.270	0.170	-0.156	0.226
	(0.374)	(0.109)	(0.368)	(0.353)
0 km< distance reduction ≤ 2 km	-0.811**	-0.137	-0.526**	-0.0897
	(0.366)	(0.109)	(0.227)	(0.225)
0-km distance reduction	-0.313	0.0137	-0.209	-0.200
	(0.303)	(0.0658)	(0.149)	(0.219)
Post-treatment municipality–subway distance > 2 km				
Distance reduction > 2 km	-0.913*	0.193	0.258	0.274
	(0.485)	(0.129)	(0.353)	(0.639)
0 km< distance reduction ≤ 2 km	-1.202***	-0.155*	-0.298	-0.157
	(0.314)	(0.0827)	(0.189)	(0.257)
0-km distance reduction (ref. cat.)	0	0	0	0
	(0)	(0)	(0)	(0)
R-squared	0.175	0.140	0.084	0.180

Notes: As for Table 6.2. *** p<0.01, ** p<0.05, * p<0.1.

As in the two previous chapters, another potential concern about the estimates in this chapter is that I could be underestimating the standard errors of my estimates due to spatial correlation between the regression errors. To address this concern, I calculate robust p-values by implementing a permutation test. Using 10.000 permutations of the key variable (categories of distance reduction) the robust p-values for my estimates of the effect of closer proximity to the subway network on robbery and larceny (columns (1) and (2) respectively in Table 6.2) are 0 and 0.009. These two robust p-values are lower than the 1 per cent significance level of the key estimates in columns (1) and (2) in Table 6.2. Hence, there is no evidence that the parametric assumptions about the correlation between the regression errors (for example, that the correlation between these regression errors is only within municipalities) underlying the specification in Table 6.2 are underestimating the magnitude of the key coefficients' standard errors.

6.5 Summary and conclusions

This chapter uses the inauguration of a 24-km new subway line and the extension of an existing one in Santiago in the mid-2000s to study changes in property crime rates. Using Chile's police records, I find evidence that robbery increased by 18 per cent in treated areas (areas that became nearer to the subway network) relative to control areas. Similarly, larceny increased by 43 per cent in treated relative to control areas. On the other hand, burglary decreased and domestic violence increased in treated relative to control areas, but in a non-significant way.

My results are consistent with the literature that states that property crime should increase when the profit—in the case of this study due to more commuters, potential victims of robbery and larceny—increases (Becker 1968 ; Fagan and Freeman 1999). In particular, my results are somehow consistent with the findings of Billings et al. (2011) who conclude that the announcement of a light rail in 2007 in Charlotte (North Carolina) decreased robbery and larceny around the new train stations.

My finding that burglary is unresponsive to changes in the transport network is not in line with studies of burglary going down as a result of greater proximity to the subway network (Billings, Leland, and Swindell 2011). Similarly, this same finding of unresponsiveness of the burglary rate to better access to employments (see Chapter 4) is not in line with the studies that have found a negative association between job accessibility and crime rates (Ihlanfeldt 2002). More specifically, the result of a non-significant association between better transport accessibility and burglary are not in line with the findings of Wang and Minor (2002) that there is less crime in areas with good job accessibility. Because most crime is committed near the criminal's domicile (Brantingham and Brantingham 1981 cited in Meaney 2004) and greater proximity to the subway network implies better labour market outcomes (see evidence in Chapter 4), an improvement in legal labour market outcomes in a certain neighbourhood could have reduced the incentives for residents to engage in illegal activities. I did not find evidence of a reduction in illegal activities.

The spatial incidence of crime (for example, as in crime hotspots) is different to the probability of being a victim. Although I find that robbery and larceny increased in treated areas, this does not necessarily imply that the probability of commuters in treated areas suffering a robbery or larceny increased. This is because the number of potential targets of robbery and larceny around the new subway stations increased after the inauguration of the subway stations. Hence, the probability of suffering a robbery or larceny could have also decreased if the proportional increase in the number of people transiting through the treated areas would have been larger than the proportional increase in property crime.

One limitation of this study is that the data does not enable us to uncover the extent to which changes in property crime were because of changes in the behaviour of potential victims, potential criminals or the police. Data on investments on private security would enable us to test whether increased investment in private security due to increased urban transport accessibility was one of the mechanisms behind the documented effect on crime rates. For this analysis, I would use a two-stage least squares estimator. In the first stage, I would test whether increased urban transport accessibility affects investment in private security. If the coefficient on the first stage is highly significant, I would then test in the second stage whether the variation of investment on private security identified in the first stage affects property crime rates.

In the case of unveiling the mechanisms underlying the increase in robbery in the public space, future studies would benefit from survey data on pedestrian flows. For uncovering the mechanisms underlying changes in both burglary and robbery, future studies would benefit from data on changes in the actions of the police in treated and control areas.

More generally, my results point out that both the journey to property crimes by offenders and the commuting behaviour of potential victims of robbery are interesting venues of research into the key factors that affect property crime.

Chapter 7

Conclusions

This thesis has examined the impacts of better urban transport accessibility in Santiago, Chile. In this chapter, I summarise my main findings and contributions, and I propose policy implications that are consistent with my findings. I also discuss ways of improving the robustness of my conclusions.

7.1 The contributions of this thesis

My thesis is the first research trying to identify the impacts of better urban transport accessibility on socioeconomic outcomes in a city in a middle-income country. In addition, in each of the empirical chapters I link large-scale datasets in employment, schooling and crime outcomes with the subway stations both before and after the expansion of the subway network in the mid-2000s. This thesis shows that it is feasible to obtain individual panel spatial data that is good and is detailed in order to evaluate the impact of spatial policies in middle-income countries like Chile.

Specifically regarding Chile, Chapter 2 is the first research to show an integrated view of a broad selection of the trends and spatial distribution of socioeconomic indicators in Santiago. Previous attempts have centred either on trends in socioeconomic indicators in Chile as a whole (Gammage, Alburquerque, and Durán 2014) or on the spatial distribution of only educational outcomes in Santiago only (Elacqua et al. 2011). In addition, as opposed to Elacqua et al. (2011) who uses educational outcomes, I use the schools' 'contextual performance indicator' (average student performance in a school accounting for socioeconomic characteristics of the students' parents) as a proxy for school valued-added. Hence, I am able to get nearer to being able to provide a map of educational opportunities in Santiago relative to previous research.

Chapters 4–6 are the first looking at the impact of greater proximity to the subway network on the labour market, academic achievement, and property crime using individual data and a credible (experimentalist) identification strategy to build valid counterfactuals to the treated individuals and areas. The contribution of this thesis also rests on the robustness of its results. By using an intent-to-treat approach in Chapters 4 and 5, I avoid selection due to heterogeneous gains from proximity to the transport innovation. In addition, by controlling for baseline characteristics in the three empirical chapters, I allow for differential trends in the outcome variable for treated and control individuals along characteristics crucially correlated with each of the outcome variables in each chapter. Moreover, by running a permutation test in Chapter 5 that does not rely on parametric assumptions about the correlation structure of the regression errors when calculating a robust p-value, I make sure that the statistical significance of my estimates is not overestimated by unaccounted spatial correlation between the regression errors. Additionally, by running a placebo test in Chapter 4 during the period before the subway expansion, I provide suggestive evidence that pre-existing differential trends in labour market outcomes in treated and control municipalities do not bias this chapter's estimates. Finally, by checking that a placebo subway expansion had no effect on academic achievement or property crime rates in Chapters 5 and 6 respectively, I show that my results are not driven by unobserved citywide shocks to academic achievement or property crime having a differential effect on treated and control individuals.

More broadly, although it was not the main purpose of this thesis, Chapters 4, 5, and 6 provide hints about why households are willing to pay for closer proximity to the subway network. Due to the decrease in academic achievement, the schooling mechanism is not a good candidate. In addition, because of the increase in robbery and larceny, the crime mechanism is also not a good candidate to the question why households benefit from better urban transport. Considering that better urban transport accessibility increases labour earnings and the probability of being employed, out of the three analysed mechanisms, the labour market channel is the best candidate for why citizens appreciate better urban transport accessibility.

7.2 The policy implications of my findings

As I show in Chapter 2, neighbourhoods with poor accessibility to the subway network in Santiago in the early 2000s had low earnings, employment rates, and schooling outcomes. Hence, any policies that might improve the socioeconomic and crime outcomes in these more deprived areas are highly relevant for policy makers in Santiago and in other large metropolitan areas sharing similar socioeconomic outcomes.

There are policy implications of three types. The first involves the intersection between urban transport and labour market outcomes. The findings of Chapter 4 show that investments in a city's rapid transit system have promising potential to improve the employment, hours of work and labour earnings of women with previously bad accessibility to employment opportunities. This is extremely important for decreasing poverty and economic inequality in countries with low female labour market participation like Chile.

The second type of policy implications is in the intersection between transport and student achievement. Schools that are going to be affected by new subway lines should consider that greater proximity to the subway network could affect its students' performance. Given the evidence presented in Chapter 5 about the greater enrolment in schools that are closer to the subway network, schools should make plans for not increasing the size of their classrooms above the desired student–teacher ratio.

The third policy implications have to do with the interaction between transport and crime. As we saw in Chapter 6, greater proximity to the subway network results in a significant increase in robbery and larceny in public space. Due to the increase in potential targets around the new subway stations, the police should increase their patrolling efforts near new subway stations.

A fourth type of policy implication crosscuts the three previous types, namely that cost-benefit analyses of transport projects undertaken by governments should consider not only the benefits in terms of time reduction, but also the wider benefits and costs in other dimensions such as labour market, academic achievement and property crime. Cost-benefit evaluations based on timesaving might yield different results than social impact evaluations based on socioeconomic, crime, and other social outcomes do. For example, a disadvantaged neighbourhood with mediocre labour market outcomes could benefit much more from a new subway line in employment terms relative to an advantaged neighbourhood with a high employment rate and labour earnings. In addition, a social cost-benefit evaluation based on timesaving does not consider equity; this is, the differential gains of different neighbourhoods relative to their baseline characteristics.

7.3 Potential future research

In this section, I explore potential future research. To stress the relevance of the proposed studies, conditional on certain results of the proposed research, I suggest possible policy implications to some of the proposed studies.

It would be interesting to integrate into a single framework to what extent citizens value the different impacts of better urban transport accessibility. This imposes several challenges. What would be the metric of the overall impact? One possibility is to use property prices as a metric of how much citizens value better transport accessibility. This line of research would be related to the work of Gibbons and Machin (2005) or Ahlfeldt (2013) who evaluated the effect of new subway stations on property prices in London in the mid-1990s, or with the work of Agostini and Palmucci (2008) who evaluated the effect of new subway stations in Santiago in the mid-2000s in Santiago. The difference with their work is that I propose to elicit the mechanisms through which better urban transport accessibility affects property prices.

Property prices reflect the citizens' willingness to pay for certain amenities when the housing market is in equilibrium. However, as argued in section 2.4, given the suggestive evidence of dwelling immobility in Chile's housing market, property prices in Santiago may not fully reflect its citizens' willingness to pay for better urban transport accessibility.

A complementary metric to property prices for capturing the benefits and disadvantages of better urban transport accessibility are measures of subjective well-being. This does not require housing markets being in equilibrium as a requisite to capture the full benefits and disadvantages of better urban transport accessibility. This approach consists of using survey data on subjective well-being before and after a change in urban transport accessibility to capture the impact of, for example, transport improvements on citizen's subjective sense of well-being.

Ideally, the data should be a panel interviewing the same individuals before and after the improvement in urban transport accessibility. As explained in Chapter 3, individual panel data enables us to control for unobserved individual fixed effects. Assuming no selection on unobservables such as the preference for better transport accessibility, we could also use cross-section data. Although this assumption is not likely to hold, Van Praag and Baarsma (2005) used cross-section data and ordered probit models to evaluate the negative impact of airport noise on citizens' well-being. Of course, potential future research of this nature would need data on the subjective well-being of citizens in affected and non-affected areas by improvements in urban transport accessibility.

Layard (2011) and Kahneman and Krueger (2006) examine reasons why subjective well-being may be a relevant metric for policy makers, and present evidence supporting the relation between subjective well-being and relevant indicators of well-being like health. One advantage of using the property prices approach over the subjective well-being one is the availability of data and the well-defined way to aggregate the welfare effect of better urban transport accessibility using money as the metric. By contrast, a weakness in using the property prices approach is that when calculating aggregate effects of a transport policy, transport projects saving a similar amount of commuting time to citizens in wealthier and poorer neighbourhoods might yield much higher benefits in wealthier neighbourhoods. The underlying reason behind this is that wealthier citizens have a higher willingness to pay for timesaving compared to poorer citizens (Mackie, Jara-Díaz, and Fowkes 2001). Hence, in terms of levels, the impact of better transport accessibility on property prices is likely to be higher in wealthier than in poorer neighbourhoods.

A second challenge, closely related to the question of 'to what extent do citizens value the different impacts of better transport accessibility' is are there other impacts which should be considered? In this thesis, I have considered the impacts on the labour market, academic achievement, and property crime. With suitable data, other dimensions could be considered. Some evidence suggests that better urban transport accessibility could have a significant impact on health outcomes. For example, MacDonald el al. (2010) provide suggestive evidence that the opening of a light rail line in Charlotte, North Carolina (USA), significantly decreased (81 per cent) the probability of obesity on the affected citizens. However, their study may be subject to selection bias. The sample in the Charlotte study is restricted to individuals living in census tracts closer than one mile (1.6 km) from the new light rail line before it started operating. While the treatment group in this study are those individuals who used the light rail six to eight months after the light rail's inauguration, the control group are those who did not use the light rail after its inauguration. Hence, one potential problem of this study is that, in the hypothetical case that the light rail would not have been opened, the estimates would be biased if health outcomes of the treated and control groups would not have followed parallel trends. This is likely to happen because the way the authors defined the treated and control groups enables self-selection into treatment[14].

On the other hand, it would be interesting to explore the effect of better urban transport on mental health and stress levels. Wener et al. (2003) study the effect on stress of the opening of a new train service in New York City in the late 1990s, stress measured by cortisol levels. They find that commuters who switched to the new service experienced lower commuting time and were less stressed relative to commuters who did not switch to the new service. Given the possible self-selection into the new route that could be correlated with changes in cortisol levels and thus bias the results, the authors conducted a second experiment in which they randomly

---

[14] A better research design would have surveyed a wider region, including households farther than two km from the new light rail stations. In this research design, the treatment group would be households that experienced a distance reduction to the light rail network and ended up closer than two kilometres from the light rail network, regardless of whether they used the light rail once inaugurated. On the other hand, the control group would be households that did not experience a distance reduction to the light rail network and were always farther than two kilometres from the light rail network.

assigned students into the new (experimental) route and the old (control) group. The results of this randomised field experiment were consistent with their previous observational study.

When integrating the impacts of better transport accessibility into a single framework that is able to uncover the main mechanisms by which well-being is affected, a third challenge is what method should be used. One possibility is to use a two-step framework. In the first step, the researcher determines the effect of better urban transport accessibility on different dimensions. This is what I have done in this thesis. These different dimensions could be socioeconomic, health, etc.. In the second step, the researcher analyses the impact of the changes in each dimension on the outcome of the overall metric (property prices, subjective well-being, income, etc.). This two-step process could be implemented using a two-stage least squares estimator.

In future research, it would be interesting to uncover the mechanisms through which greater proximity to the subway network increases the female employment rate. If the increase in the female labour rate is related to commuting time-saving, then an alternative (and less expensive than subways) policy could be to invest in bus lanes that could save time for commuters residing in low-density areas not suitable for rapid transit systems (Levinson et al. 2003). Alternatively, if the increase in female labour supply is related to comfort and less sexual harassment (Smith 2008), then an alternative policy to subways could be priority seats in buses during rush hours. To analyse which mechanism is most important, I would implement a more structural approach than the approach in Chapter 4 by modelling explicitly the effect of commuting time-saving, comfort and less sexual harassment on women's decision to participate in the labour market.

7.4 Improving the robustness of my conclusions

In this section, I explore what kind of data would have improved the robustness of my conclusions.

In Chapter 2, when constructing a map of educational opportunities in Santiago in the early-2000s (the period before the subway expansion), I would have benefitted from school value-added measures. To obtain value-added measures that are not prone to composition bias due to students changing schools I need panels of students. Unfortunately, there are no panels with standardised test scores in Santiago during the early 2000s. The first panel with standardised test scores in Santiago was the one with students who took the SIMCE test in eighth and tenth grade in 2004 and 2006 respectively (panel I am using in Chapter 5). Average school value-added measures would have been an improvement over my measure of ‘contextual average student performance’ because the former measure is not affected by heterogeneity in students’ academic skills between schools. At least two characteristics of school systems increase the heterogeneity in students' academic skills between schools: the capacity of schools to select students by academic ability, and the non-existence of catchment areas. In school systems with no catchment areas, students have more freedom to self-select into higher performing and lower performing schools according to their academic skills relative to systems with catchment areas. As explained in Section 2.2.2, the two previously described characteristics are present in Chile's school system. Hence, appropriate data to calculate value-added measures could potentially improve the accuracy of the map of educational opportunity I present in Section 2.3.6. Unfortunately, to my knowledge, this data does not exist for Santiago during the early 2000s.

Chapter 4 uses individual data with the workers’ residence aggregated at Santiago’s municipal level. The precision of estimates in this Chapter would benefit from a dataset with individual addresses and the same level of detail in covariates as in the Panel Casen dataset. With the location of workers’ residences aggregated at the municipal level, the spatial model situates each worker at the centroid of their municipality of residence. Using individual addresses would also enable me to allow for differential labour market trends for individuals residing in different municipalities (in a similar fashion to what I do in Chapters 5 and 6). In other words, individual addresses would enable me to remove any potential bias from a correlation between the mayors’ capacity to lobby for the new subway line and the implementation of municipal policies that could have stimulated the residents’ labour market outcomes. Unfortunately, due to confidentiality issues, I was not able to gain access to the addresses of individuals in the Panel

Casen dataset or other comparable datasets in Chile like the '*Encuesta de Protección Social*' ('Social Protection Survey').

With data on each student's residential address, the results in Chapter 5 could have offered a more comprehensive view of the effects of urban transport accessibility on academic achievement. The address of each school enabled me to assess the effect of greater proximity between the school and the nearest subway station on academic achievement. On the other hand, having each student's residential address would have enabled me to assess the effect of greater proximity between the students' residential address and the nearest subway station on academic achievement. Bearing in mind that in 2002 the average distance between students in fourth grade and their school was 1.9 km (approximately what we defined as 'walking distance' in Chapter 5) (Gallego and Hernando 2009), not necessarily the effects of student–subway network proximity and school–subway network proximity are the same. We can easily think about individual cases where the subway expansion increased the residence–subway proximity but not the school–subway proximity for many students.

As mentioned in Chapter 1, one way of improving the robustness of the conclusions in this thesis is by using instruments. It could be argued that, conditional on individual and place-based initial characteristics, the selection of the route of the new subway line and the location of the stations could be endogenous to residents' socioeconomic outcomes. I could address this concern by using instruments that could only have affected socioeconomic outcomes by determining the route of the new subway line.

One possibility of such an instrument is using the planned route instrumental variable. As mentioned in section 2.1.4, a master plan for Santiago's subway network dating from 1968 included a primitive layout for the city's first five subway lines, including the new line (Line 4) and the extensions analysed in this thesis. I could use the distance reduction to the planned lines according to the 1968 plan as an instrument for the actual distance reduction to the subway network that took place in the mid-2000s. This 'planned route IV' (following Redding and Turner's (2014) terms for the different instrumental variable approaches) was pioneered by Baum-Snow (2007) who used planned portions of the US interstate highway system as an instrument for the actual increase in highways in the USA between 1950 and 1990. To implement an instrumental variables approach using this first approach I would need the exact route of each planned subway line. This data should be available from Chile's Government Transport Planning office. This approach could help solve a potential endogeneity between the chosen route for the new subway line and changes in socioeconomic outcomes.

A second potential instrument is given by what Redding and Turner (2014) call the 'inconsequential units approach'. To apply this approach to the setting of this thesis, I could connect the downtown of Puente Alto (the municipality in the south of Greater Santiago served by the new subway line) with a least cost path to the downtown of the municipality of Santiago. Assuming that the neighbourhoods in the middle of this 'least cost path' between both downtowns were 'accidentally' connected, I could use such path as an instrument for the actual route of the subway line that opened in the mid-2000s. This approach was pioneered by Chandra and Thompson (2000) in the analysis of the effect of highways on economic activity in the USA and has been applied more recently, among other, by Faber (2014) to study the effect of highways on economic activity in China.

References

Abadie, Alberto, and Sofia Dermisi. 2008. "Is Terrorism Eroding Agglomeration Economies in Central Business Districts? Lessons from the Office Real Estate Market in Downtown Chicago." *Journal of Urban Economics* 64 (2): 451–63.

Acemoglu, Daron, and David Autor. 2009. "Lectures in Labor Economics." *Unpublished Manuscript, Department of Economics, Massachusetts Institute of Technology, Cambridge, MA. Retrieved from Http://economics. Mit. edu/files/4689*.

Agencia de la Calidad, Ministerio de Educación de Chile. 2014. "Los Aprendizajes En La Escuela: Ampliando La Mirada de Calidad. Resultados 2013." presented at the Conferencia nacional resultados SIMCE 2013, October 6. https://s3-us-west-2.amazonaws.com/resultados-simce-2013/Conferencia_Nacional_ResultadosSimce2013.pdf.

Agostini, Claudio A, and Gastón A Palmucci. 2008. "The Anticipated Capitalisation Effect of a New Metro Line on Housing Prices." *Fiscal Studies* 29 (2): 233–56.

Ahlfeldt, Gabriel M. 2013. "If We Build It, Will They Pay? Predicting Property Price Effects of Transport Innovations." *Environment and Planning A* 45 (8): 1977–94.

Alonso, William. 1964. *Location and Land Use: Toward a General Theory of Land Rent*. Cambridge, MA: Harvard University Press.

Angrist, Joshua D., and Alan B. Krueger. 1991. "Does Compulsory School Attendance Affect Schooling and Earnings?" *The Quarterly Journal of Economics* 106 (4): 979–1014.

———. 1999. "Chapter 23 Empirical Strategies in Labor Economics." In *Handbook of Labor Economics*, Volume 3, Part A:1277–1366. Elsevier. http://www.sciencedirect.com/science/article/pii/S1573446399030047.

Arriagada, Camilo, and Daniela Simioni. 2001. *Dinámica de valorización del suelo en el área metropolitana del Gran Santiago y desafíos del financiamiento urbano*. Santiago de Chile: Naciones Unidas, CEPAL, División de Medio Ambiente y Asentamientos Humanos.

Åslund, Olof, John Östh, and Yves Zenou. 2010. "How Important Is Access to Jobs? Old Question—Improved Answer." *Journal of Economic Geography* 10 (3): 389–422.

Atina Chile! 2005. "Estación Maipú celebra el anuncio del Metro." *atinachile.cl*. November 15. http://www.atinachile.cl/content/view/5591/Estacion-Maipu-celebra-el-anuncio-del-Metro.html.

Banco Central de Chile. 2014a. "Estadísticas Económicas - Banco Central de Chile: PIB Regional." http://www.bcentral.cl/estadisticas-economicas/publicaciones-estadisticas/.

———. 2014b. "National Accounts." http://si3.bcentral.cl/Siete/secure/cuadros/arboles.aspx.

Banerjee, Abhijit V., Shawn Cole, Esther Duflo, and Leigh Linden. 2007. "Remedying Education: Evidence from Two Randomized Experiments in India." *The Quarterly Journal of Economics* 122 (3): 1235–64. doi:10.1162/qjec.122.3.1235.

Baum-Snow, Nathaniel. 2007. "Did Highways Cause Suburbanization?" *The Quarterly Journal of Economics* 122 (2): 775–805.

BBC News. 2006. "Chile Student Rally Turns Violent." *BBC*, August 23, sec. Americas. http://news.bbc.co.uk/1/hi/world/americas/5277190.stm.

Becker, Gary S. 1968. "Crime and Punishment: An Economic Approach." *Journal of Political Economy* 76 (2): 175–209.

Bendezú, Luis, Angela M. Denis, and José R. Zubizarreta. 2007. "Análisis de La Atrición de La Muestra En La Encuesta Panel CASEN." *Santiago de Chile: Observatorio Social Universidad Alberto Hurtado*.

Bennett, Trevor, and Richard Wright. 1984. *Burglars on Burglary: Prevention and the Offender*. Aldershot: Gower.

Billings, Stephen B., Suzanne Leland, and David Swindell. 2011. "The Effects of the Announcement and Opening of Light Rail Transit Stations on Neighborhood Crime." *Journal of Urban Affairs* 33 (5): 549–66.

Black, Dan A., Natalia Kolesnikova, and Lowell J. Taylor. 2014. "Why Do so Few Women Work in New York (and so Many in Minneapolis)? Labor Supply of Married Women across US Cities." *Journal of Urban Economics*, Spatial Dimensions of Labor Markets, 79 (January): 59–71.

Block, R., and S. Davis. 1996. "The Environs of Rapid Transit Stations: A Focus for Street Crime or Just Another Risky Place?" *Preventing Mass Transit Crime*, 237–57.

Brain, Isabel, Francisco Sabatini, and Andres Iacobelli. 2005. "Calidad Y Valor de La Vivienda Social, Un Problema de Localización Y Barrio." *Revista ProUrbana* 2. http://politicaspublicas.uc.cl/media/publicaciones/pdf/20100622222858.pdf.

Brantingham, Paul J., and Patricia L. Brantingham. 1981. "Notes on the Geometry of Crime." In *Environmental Criminology*, 27–54. London: Sage Pulications Ltd.

———. 1984. *Patterns in Crime*. New York: Macmillan. https://www.ncjrs.gov/App/Publications/abstract.aspx?ID=110611.

Browder, John O., James R. Bohland, and Joseph L. Scarpaci. 1995. "Patterns of Development on the Metropolitan Fringe: Urban Fringe Expansion in Bangkok, Jakarta, and Santiago." *Journal of the American Planning Association* 61 (3): 310–27.

Capone, Donald L., and Woodrow W. Nichols. 1976. "Urban Structure and Criminal Mobility." *The American Behavioral Scientist* 20 (2). http://search.proquest.com.gate2.library.lse.ac.uk/docview/1306753478/citation?accountid=9630.

Card, David, Martin D Dooley, and A. Abigail Payne. 2010. "School Competition and Efficiency with Publicly Funded Catholic Schools." *American Economic Journal: Applied Economics* 2 (4): 150–76.

Card, David, and Alan B. Krueger. 1992. "Does School Quality Matter? Returns to Education and the Characteristics of Public Schools in the United States." *Journal of Political Economy* 100 (1): 1–40.

Chandra, Amitabh, and Eric Thompson. 2000. "Does Public Infrastructure Affect Economic Activity?: Evidence from the Rural Interstate Highway System." *Regional Science and Urban Economics* 30 (4): 457–90.

Chen, Yihsu, and Alexander Whalley. 2012. "Green Infrastructure: The Effects of Urban Rail Transit on Air Quality." *American Economic Journal: Economic Policy* 3 (4): 58–97.

Chetty, Raj, John N. Friedman, and Jonah E. Rockoff. 2011. "The Long-Term Impacts of Teachers: Teacher Value-Added and Student Outcomes in Adulthood." Working Paper 17699. National Bureau of Economic Research. http://www.nber.org/papers/w17699.

Chetty, Raj, Nathaniel Hendren, Patrick Kline, and Emmanuel Saez. 2014. "Where Is the Land of Opportunity? The Geography of Intergenerational Mobility in the United States." Working Paper 19843. National Bureau of Economic Research. http://www.nber.org/papers/w19843.

Cogan, J. 1981. *Fixed Costs and Labor Supply*. Vol. 49. Econometrica.

COPESA. 2010. "Icarito: Región Metropolitana de Santiago." http://www.icarito.cl/enciclopedia/articulo/segundo-ciclo-basico/historia-geografia-y-ciencias-sociales/geografia-general-y-regional-de-chile/2010/06/85-6799-9-4-region-metropolitana-de-santiago.shtml.

Coulson, N. Edward, Derek Laing, and Ping Wang. 2001. "Spatial Mismatch in Search Equilibrium." *Journal of Labor Economics* 19 (4): 949–72.

D'Costa, Sabine, Steve Gibbons, Henry Overman, and Panu Pelkonen. 2013. "Agglomeration and Labour Markets: The Impact of Transport Investments on Labour Market Outcomes." In *Geography, Institutions and Regional Economic Performance*, edited by Riccardo Crescenzi and Marco Percoco, 263–79. Advances in Spatial Science. Springer Berlin Heidelberg. http://link.springer.com/chapter/10.1007/978-3-642-33395-8_13.

Department for Education. 2014. "Value Added Technical Information." *School Performance Tables*. http://www.education.gov.uk/schools/performance/archive/schools_04/sec3b.shtml.

Department for Transport, Great Minster House. 2011. "Households with Good Transport Access to Key Services or Work." Dataset. May 13. http://www.dft.gov.uk/publications/dft-business-plan-indicators-impact-07/.

De Ramón, Armando. 1992. *Santiago de Chile (1541-1991): historia de una sociedad urbana*. Editorial MAPFRE. https://www.scribd.com/doc/23658311/Ramon-Armando-de-Santiago-de-Chile-Historia-de-Una-Sociedad-Urbana.

Dickerson, Andy, and Steven McIntosh. 2013. "The Impact of Distance to Nearest Education Institution on the Post-Compulsory Education Participation Decision." *Urban Studies* 50 (4): 742–58.

Duncan, Otis Dudley, and Beverly Duncan. 1955. "A Methodological Analysis of Segregation Indexes." *American Sociological Review* 20 (2): 210–17.

Duranton, Gilles, and Matthew A. Turner. 2012. "Urban Growth and Transportation." *The Review of Economic Studies* 79 (4): 1407–40.

Ehrlich, Isaac. 1973. "Participation in Illegitimate Activities: A Theoretical and Empirical Investigation." *Journal of Political Economy* 81 (3): 521–65.

Elacqua, Gregory, Matias Martinez, Felipe Salazar, and Humberto Santos. 2011. "Geografía de Las Oportunidades Educacionales En Chile." *Instituto de Políticas Públicas - Universidad Diego Portales Working Paper*. http://www.politicaspublicas.udp.cl/media/publicaciones/archivos/281/Documento_completo.pdf.

El Mercurio. 2012. "Travel Times in Santiago." http://www.mer.cl/Pages/NewsDetail.aspx?dt=2012-03-20&PaginaId=8&bodyid=3.

Faber, Benjamin. 2014. "Trade Integration, Market Size, and Industrialization: Evidence from China's National Trunk Highway System*." *The Review of Economic Studies*, March, rdu010.

Fagan, Jeffrey, and Richard B. Freeman. 1999. "Crime and Work." *Crime and Justice* 25 (January): 225–90.

Falch, Torberg, Päivi Lujala, and Bjarne Strøm. 2013. "Geographical Constraints and Educational Attainment." *Regional Science and Urban Economics* 43 (1): 164–76.

Ferreira, Robert, and Tharcisiu Alves. 2012. "Sao Paulo Metro." *Www.nycsubway.org*. http://www.nycsubway.org/wiki/Main_Page.

Fisher, Ronald A. 1935. *The Design of Experiments*. Vol. xi. Oxford, England: Oliver & Boyd.

Fitzgerald, John, Peter Gottschalk, and Robert Moffitt. 1998. "An Analysis of Sample Attrition in Panel Data." *Journal of Human Resources* 33 (2): 251–99.

Freeman, Richard B. 1999. "Chapter 52 The Economics of Crime." In *Handbook of Labor Economics*, Volume 3, Part C:3529–71. Elsevier. http://www.sciencedirect.com/science/article/pii/S1573446399300432.

Gallego, Francisco A., and Andres Hernando. 2009. "School Choice in Chile: Looking at the Demand Side." SSRN Scholarly Paper ID 1725911. Rochester, NY: Social Science Research Network. http://papers.ssrn.com/abstract=1725911.

Gallego, Francisco A., and Andrés E. Hernando. 2008. "On the Determinants and Implications of School Choice: Semi-Structural Simulations for Chile." *Economía* 9 (1): 197–239.

Gammage, Sarah, Tomás Alburquerque, and Gonzálo Durán. 2014. "Poverty, Inequality and Employment in Chile." International Labour Organization. http://natlex.ilo.ch/wcmsp5/groups/public/---ed_protect/---protrav/---travail/documents/publication/wcms_248029.pdf.

Gaubatz, Piper. 1999. "China's Urban Transformation: Patterns and Processes of Morphological Change in Beijing, Shanghai and Guangzhou." *Urban Studies* 36 (9): 1495–1521.

Gibbons, S., and S. Machin. 2003. "Employment and Rail Access: An Evaluation of the Wider Benefits of Transport Improvements." London: Department for Transport. Available at: http://www. dft. gov. uk/pgr/economics/rdg/employmentandrailaccessaneva3065.

Gibbons, Stephen, and Stephen Machin. 2005. "Valuing Rail Access Using Transport Innovations." *Journal of Urban Economics* 57 (1): 148–69.

———. 2006. "Transport and Labour Market Linkages: Empirical Evidence, Implications for Policy and Scope for Further UK Research." *Commissioned for the Eddington Study*.

Gibbons, Stephen, and Henry G. Overman. 2012. "Mostly Pointless Spatial Econometrics?" *Journal of Regional Science* 52 (2): 172–91.

Gibbons, Stephen, Olmo Silva, and Stephen Machin. 2008. "Choice, Competition, and Pupil Achievement." *Journal of the European Economic Association* 6 (4): 912–47.

Gibbons, Stephen, Olmo Silva, and Felix Weinhardt. 2013. "Everybody Needs Good Neighbours? Evidence from Students' Outcomes in England." *The Economic Journal* 123 (571): 831–74.

Gibbons, Stephen, and Shqiponja Telhaj. 2011. "Pupil Mobility and School Disruption." *Journal of Public Economics* 95 (9–10): 1156–67.

Gilbert, Alan. 2004. "Helping the Poor through Housing Subsidies: Lessons from Chile, Colombia and South Africa." *Habitat International* 28 (1): 13–40.

Gimenez Nadal, Jose Ignacio, and José Alberto Molina. 2011. "Commuting Time and Labour Supply: A Causal Effect?" IZA Discussion Paper 5529. Institute for the Study of Labor (IZA). http://econpapers.repec.org/paper/izaizadps/dp5529.htm.

Glaeser, Edward. 2011. *Triumph of the City: How Our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier and Happier*. New York: The Penguin Press.

Glaeser, Edward L., Matthew E. Kahn, and Jordan Rappaport. 2008. "Why Do the Poor Live in Cities? The Role of Public Transportation." *Journal of Urban Economics* 63 (1): 1–24.

Godoy, Daniela, and Constanza Gillmore. 2009. "Análisis Encuesta Nacional de Victimización: Construcción de un perfil de quienes tienen mayor percepción de que la delincuencia va en aumento y quienes realmente la sufren." *Informe especial* XX (213). https://www.oas.org/dsp/documents/victimization_surveys/chile/Chile%20-%20Analisis%20Encuesta%20de%20Victimizacion.pdf.

Google Maps. 2014. "Chile." https://www.google.co.uk/maps/preview?oe=utf-8&client=firefox-a&channel=fflb&ie=UTF-8&fb=1&gl=uk&sll=-35.675147,-71.542969&sspn=6.8819468,11.3193047&q=Chile&ei=r4UIVIWAMorm8AXnyYGQBg&ved=0CJ4BEPIBMBI.

Gordon, Peter, Ajay Kumar, and Harry W. Richardson. 1989. "Gender Differences in Metropolitan Travel Behaviour." *Regional Studies* 23 (6): 499–510.

Gschwender, Antonio. 2005. "Improving the Urban Public Transport in Developing Countries: The Design of a New Integrated System in Santiago de Chile." In . Vol. Thredbo 9. http://ses.library.usyd.edu.au/handle/2123/6129.

Hanushek, Eric A., John F. Kain, and Steven G. Rivkin. 2004. "Disruption versus Tiebout Improvement: The Costs and Benefits of Switching Schools." *Journal of Public Economics* 88 (9–10): 1721–46.

Harrington, Victoria, and Patricia Mayhew. 2001. *Mobile Phone Theft*. London: Home Office. https://martinfrost.ws/htmlfiles/Mobile_phone_theft.pdf.

Helderman, Amanda C., Clara H. Mulder, and MaartenVan Ham. 2004. "The Changing Effect of Home Ownership on Residential Mobility in the Netherlands, 1980–98." *Housing Studies* 19 (4): 601–16.

Herrnstein, Richard J., and Charles Murray. 2010. *Bell Curve: Intelligence and Class Structure in American Life*. Simon and Schuster.

Hidalgo-Dattwyler, Rodrigo. 2004. "La Vivienda Social En Santiago de Chile En La Segunda Mitad Del Siglo XX: Actores Relevantes Y Tendencias Espaciales." In *Santiago En La Globalización:¿ Una Nueva Ciudad?*, 219–41. Santiago de Chile: Ediciones SUR. http://www.sitiosur.cl/publicaciones/Ediciones_Sur/santiago_en_la_globalizacion.pdf#page=219.

Ihlanfeldt, Keith. 2002. "Spatial Mismatch in the Labor Market and Racial Differences in Neighborhood Crime." *Economics Letters* 76 (1): 73–76.

Instituto Nacional de Estadisticas. 2005. "Censo 2002." http://www.ine.cl/canales/chile_estadistico/demografia_y_vitales/demografia/pdf/cdpubaldcasjunio2005.zip.

Instituto Nacional de Estadisticas, Chile. 2010. "Nueva Encuesta Nacional de Empleo - Manual Conceptual Y Metodologico de Diseño Muestral." http://www.ine.cl/canales/chile_estadistico/mercado_del_trabajo/empleo/metodologia/pdf/031110/manual_metodologico031110.pdf.

———. 2014. "Proyecciones de Población." http://palma.ine.cl/demografia/cd/Excel2003/DatCom%5CSalComUsuarios-13Tok.xls.

Instituto Nacional de Estadísticas de Chile. 2014a. "Productos Estadísticos: Laborales." http://www.ine.cl/canales/chile_estadistico/mercado_del_trabajo/empleo/series_estadisticas/nuevas_empalmadas/series_fecha.php.

———. 2014b. "Programa de Proyecciones de La Población." http://www.ine.cl/canales/chile_estadistico/demografia_y_vitales/proyecciones/MenPrincOK.xls.

International Monetary Fund. 2014. "World Economic Outlook Database April 2014." April. http://www.imf.org/external/pubs/ft/weo/2014/01/weodata/index.aspx.

Jacobs, Jane. 1961. *The Death and Life of Great American Cities*. New York: Random House. http://scholar.google.co.uk/scholar?hl=en&q=Jacobs+1961+The+death+and+life+of+great+American+cities&btnG=&as_sdt=1%2C5&as_sdtp=.

Jedwab, Rémi, and Alexandre Moradi. 2011. "Transportation Infrastructure and Development in Ghana." PSE Working Paper halshs-00607207. HAL. https://ideas.repec.org/p/hal/psewpa/halshs-00607207.html.

Johnson, Ryan M., David H. Reiley, and Juan Carlos Muñoz. 2005. "'The War for the Fare': How Driver Compensation Affects Bus System Performance." National Bureau of Economic Research. http://www.nber.org/papers/w11744.

Kahneman, Daniel, and Alan B. Krueger. 2006. "Developments in the Measurement of Subjective Well-Being." *The Journal of Economic Perspectives* 20 (1): 3–24.

Koppen, Peter J, and Jan W Keijser. 1997. "Desisting Distance Decay: On the Aggregation of Individual Crime Trips." *Criminology* 35 (3): 505–15.

Kremer, M., C. Brannen, and R. Glennerster. 2013. "The Challenge of Education and Learning in the Developing World." *Science* 340 (6130): 297–300.

Krueger, Alan B. 1999. "Experimental Estimates of Education Production Functions." *The Quarterly Journal of Economics* 114 (2): 497–532.

Krueger, Alan B., and Diane M. Whitmore. 2001. "The Effect of Attending a Small Class in the Early Grades on College-Test Taking and Middle School Test Results: Evidence from Project Star." *The Economic Journal* 111 (468): 1–28.

Lachin, John M. 2000. "Statistical Considerations in the Intent-to-Treat Principle." *Controlled Clinical Trials* 21 (3): 167–89.

Latin Correspondent. 2014. "Chile Announces $4.2B Transportation Plan." *Latin Correspondent*. May 11. http://latincorrespondent.com/chile/chile-announces-4-2b-transportation-plan/.

Layard, Richard. 2011. *Happiness: Lessons from a New Science (Second Edition)*. London: Penguin UK.

Levinson, Herbert S., Samuel Zimmerman, Jennifer Clinger, and James Gast. 2003. "Bus Rapid Transit: Synthesis of Case Studies." *Transportation Research Record: Journal of the Transportation Research Board* 1841 (1): 1–11.

Liggett, R., A. Loukaitou-Sideris, and H. Iseki. 2003. "Journeys to Crime: Assessing the Effects of a Light Rail Line on Crime in the Neighborhoods."

Little, Roderick, and Linda Yau. 1996. "Intent-to-Treat Analysis for Longitudinal Studies with Drop-Outs." *Biometrics* 52 (4): 1324–33. doi:10.2307/2532847.

Ludwig, Jens, Greg J. Duncan, Lisa A. Gennetian, Lawrence F. Katz, Ronald C. Kessler, Jeffrey R. Kling, and Lisa Sanbonmatsu. 2012. "Neighborhood Effects on the Long-Term Well-Being of Low-Income Adults." *Science* 337 (6101): 1505–10.

MacDonald, John M., Robert J. Stokes, Deborah A. Cohen, Aaron Kofner, and Greg K. Ridgeway. 2010. "The Effect of Light Rail Transit on Body Mass Index and Physical Activity." *American Journal of Preventive Medicine* 39 (2): 105–12.

Machin, Stephen, and Costas Meghir. 2004. "Crime and Economic Incentives." *Journal of Human Resources* 39 (4): 958–79.

Mackie, P. J., S. Jara-Díaz, and A. S. Fowkes. 2001. "The Value of Travel Time Savings in Evaluation." *Transportation Research Part E: Logistics and Transportation Review*, Advances in the Valuation of Travel Time Savings, 37 (2–3): 91–106.

Madaleno, Isabel Maria, and Alberto Gurovich. 2004. "'Urban versus Rural' No Longer Matches Reality: An Early Public Agro-Residential Development in Periurban Santiago, Chile." *Cities* 21 (6): 513–26.

Maguire, Mike. 2012. "Criminal Statistics and the Construction of Crime." In *The Oxford Handbook of Criminology*, 5th ed., 206–44. Oxford: Oxford University Press.

Massey, Douglas S., and Mitchell L. Eggers. 1990. "The Ecology of Inequality: Minorities and the Concentration of Poverty, 1970-1980." *American Journal of Sociology* 95 (5): 1153–88.

Meaney, Rebecca. 2004. "Commuters and Marauders: An Examination of the Spatial Behaviour of Serial Criminals." *Journal of Investigative Psychology and Offender Profiling* 1 (2): 121–37.

Metro de Santiago. 2014. "Historia del Metro de Santiago." *Metro de Santiago*. September 29. http://www.metrosantiago.cl/corporativo/historia.

Michaels, Guy. 2008. "The Effect of Trade on the Demand for Skill: Evidence from the Interstate Highway System." *Review of Economics and Statistics* 90 (4): 683–701.

Ministerio de Desarrollo Social de Chile. 2012a. "CASEN 2011: Encuesta de Caracterización Socioeconómica Nacional." July 20. http://observatorio.ministeriodesarrollosocial.gob.cl/layout/doc/casen/publicaciones/2011/CASEN_2011.pdf.

———. 2012b. "Casen Survey." September 13. http://observatorio.ministeriodesarrollosocial.gob.cl/basededatos.php.

Ministerio de Economía, Gobierno de Chile. 2009. "Indicadores de Desarrollo Digital de Chile." June 24. http://intrawww.ing.puc.cl/siding/public/ingcursos/cursos_pub/descarga.phtml?id_curso_ic=2069&id_archivo=76886.

Ministerio del Interior y Seguridad Pública. 2014a. "ENUSC 2013 Región Metropolitana." March.

http://www.seguridadpublica.gov.cl/filesapp/13_METROPOLITANA_%20ENUSC 2013_FINAL_final.pdf.

———. 2014b. "ENUSC 2013 Resultados País." March. http://www.seguridadpublica.gov.cl/filesapp/PAIS%20ENUSC%202013%20Final.pdf.

Ministerio de Planificación. 2005. "Metodologia Encuesta CASEN 1987–1998." Ministerio de Planificación de Chile. http://www.ministeriodesarrollosocial.gob.cl/casen/pdf/Metodologia_1987_1998.pdf.

Miranda-Moreno, Luis F., Patrick Morency, and Ahmed M. El-Geneidy. 2011. "The Link between Built Environment, Pedestrian Activity and Pedestrian–vehicle Collision Occurrence at Signalized Intersections." *Accident Analysis & Prevention* 43 (5): 1624–34.

Mizala, Alejandra, Pilar Romaguera, and Miguel Urquiola. 2007. "Socioeconomic Status or Noise? Tradeoffs in the Generation of School Quality Information." *Journal of Development Economics* 84 (1): 61–75.

Montenegro, Claudio E., and Carmen Pagés. 2004. "Who Benefits from Labor Market Regulations? Chile, 1960–1998." In *Law and Employment Lessons from Latin America and the Caribbean*, 401–34. Chicago: University of Chicago Press. http://site.ebrary.com/id/10210025.

Moscow City Government. 2014. "A Visit to a Section of Smaller Moscow Belt Railway under Construction." *The Website of the Mayor and the Government of Moscow*. http://www.mos.ru/en/press-center/themes/index.php?search_4=1109&view_mode_4=tag_search&view_module_4=anywhere.

Neal, Derek A., and William R. Johnson. 1996. "The Role of Premarket Factors in Black-White Wage Differences." *Journal of Political Economy* 104 (5): 869–95.

Nickell, Stephen. 1981. "Biases in Dynamic Models with Fixed Effects." *Econometrica* 49 (6): 1417–26.

Observatorio de Ciudades Universida Católica de Chile. 2011. "Density of Building Permits and Location of Publicly Subsidised Affordable Housing." Santiago, Chile. http://www.ocuc.cl/wp-content/downloads/planos_1990-2002/11_vivsocial+densedif.pdf.

OECD. 2010. *PISA 2009 Results: Overcoming Social Background*. PISA. OECD Publishing. http://www.oecd-ilibrary.org/education/pisa-2009-results-overcoming-social-background_9789264091504-en.

———. 2013. *PISA 2012 Results: Excellence through Equity (Volume II)*. PISA. OECD Publishing. http://www.keepeek.com/Digital-Asset-Management/oecd/education/pisa-2012-results-excellence-through-equity-volume-ii_9789264201132-en#page1.

———. 2014a. "OECD.Stat." doi:http://dx.doi.org/10.1787/data-00285-en.

———. 2014b. "OECD Statistics." http://stats.oecd.org/.

Oxford University Press. 2014. "Oxford Dictionaries." http://www.oxforddictionaries.com/definition/english/larceny.

Ozimek, Adam, and Daniel Miles. 2011. "Stata Utilities for Geocoding and Generating Travel Time and Travel Distance Information." *Stata Journal* 11 (1): 106–19.

Pagliara, Francesca, and Enrica Papa. 2011. "Urban Rail Systems Investments: An Analysis of the Impacts on Property Values and Residents' Location." *Journal of Transport Geography* 19 (2): 200–211.

Palmer, Montserrat. 2014. "La Comuna de Providencia Y La Ciudad Jardín." *Revista EURE-Revista de Estudios Urbano Regionales* 11 (31). http://scholar.google.co.uk/scholar?cluster=8092591263591964523&hl=en&as_sdt=0,5.

Pávez Reyes, María Isabel. 2007. "Vialidad, Transporte y Planeamiento urbano-regional en Santiago de Chile, 1950-1979." *Cuadernos de Investigación Urbanística* 51 (1). http://polired.upm.es/index.php/ciur/article/view/266.

Phillips, David. 2012. "Getting to Work: Experimental Evidence on Job Search and Transportation Costs." *National Poverty Center Working Paper Series* #12 – 03. http://npc.umich.edu/publications/u/2012-03%20NPC%20Working%20Paper.pdf.

PISA. 2013. "Ready to Learn: Students' Engagement, Drive and Self-Beliefs – Volume III. PISA 2012 Technical Background: Annex A." http://disde.minedu.gob.pe/xmlui/handle/123456789/2489.

———. 2014. "PISA Test Databases." http://www.oecd.org/pisa/pisaproducts/.

Poister, Theodore H. 1996. "Transit-Related Crime in Suburban Areas." *Journal of Urban Affairs* 18 (1): 63–75.

Portes, Alejandro, and Bryan R. Roberts. 2005. "The Free-Market City: Latin American Urbanization in the Years of the Neoliberal Experiment." *Studies in Comparative International Development* 40 (1): 43–82.

Radio Cooperativa. 2001. "Lagos anunciará hoy extensión del metro hasta Puente Alto." News website. *Cooperativa.cl*. May 17. http://www.cooperativa.cl/noticias/pais/lagos-anunciara-hoy-extension-del-metro-hasta-puente-alto/2001-05-17/090100.html.

Rattner, Arye, and Boris Portnov. 2007. "Distance Decay Function in Criminal Behavior: A Case of Israel." *The Annals of Regional Science* 41 (3): 673–88.

Recabarren, Javier. 2008. "La Migración de Las Elites Hacia El Oriente de Santiago: El Caso de La Comuna de Providencia. 1895-1930." *Encrucijada Americana* 2 (1): 141–66.

Redding, Stephen J., and Matthew A. Turner. 2014. "Transportation Costs and the Spatial Organization of Economic Activity." *NBER Working Paper Series*, no. 20235 (June). http://www.nber.org/papers/w20235.pdf.

Rockoff, Jonah E. 2004. "The Impact of Individual Teachers on Student Achievement: Evidence from Panel Data." *The American Economic Review* 94 (2): 247–52.

Rodríguez, Jorge, and Camilo Arriagada. 2004. "Segregación Residencial En La Ciudad Latinoamericana." *Eure (Santiago)* 30 (89): 05–24.

Sanchis-Guarner, Rosa. 2012. "Driving Up Wages: The Effects of Road Construction in Great Britain." *Spatial Economics Research Centre Discussion Paper* 120. http://www.cepr.org/sites/default/files/SANCHIS-GUARNER%20-%20Transport_labour_Sept13_CURE.pdf.

Sanhueza, Claudia, and Pablo Celhay. 2011. "Location, Location, Location, Labor Otcomes in Urban Slums of Santiago-Chile." *IPP Working Paper No. 3. Instituto de Políticas Públicas, Facultad de Economía Y Empresa, Universidad Diego Portales, Santiago, Chile*.

SECTRA. 2002. "Encuesta Origen Destino de Viajes, Santiago 2001 – Informe de Difusión." Santiago, Chile: Secretaría de Transportes (SECTRA), Gobierno de Chile. http://www.subtrans.gob.cl/subtrans/doc/estadisticas-EOD2001_Informe_Difusion.pdf.

Simian, José Miguel. 2010. "Logros Y Desafíos de La Política Habitacional En Chile." *Estudios Públicos* 117 (Verano): 269–322.

Skogan, Wesley G., and Michael G. Maxfield. 1981. *Coping with Crime: Individual and Neighborhood Reactions*. Beverly Hills: Sage Publications. http://skogan.org/files/Coping_With_Crime_-_Individual_and_Neighborhood_Reactions.pdf.

Smith, Martha J. 2008. "Addressing the Security Needs of Women Passengers on Public Transport." *Security Journal* 21 (1): 117–33. doi:10.1057/palgrave.sj.8350071.

Socio-Economic Database for Latin America and the Caribbean. 2014a. "SEDLAC - Dynamic Searches." http://sedlac.econo.unlp.edu.ar/eng/dynamics-searches.php.

———. 2014b. "SEDLAC Statistics: Employment and Unemployment Rates." http://sedlac.econo.unlp.edu.ar/download.php?file=archivos_estadistica/employment_LAC_2013-12.xls.

The Branding Brothers. 2008. "Donde Ir En Santiago Si Hacen La Cimarra..!! | Estudiantes Secundarios." *Secundarios.com*. October 12. http://www.secundarios.com/estudiantes/threads/donde-ir-en-santiago-si-hacen-la-cimarra.48347/.

TriMet. 2013. "Portland-Milwaukie Light Rail Project: About the Project." http://www.trimet.org/pm/abouttheproject/index.htm.

Tseloni, Andromachi, Karin Wittebrood, Graham Farrell, and Ken Pease. 2004. "Burglary Victimization in England and Wales, the United States and the Netherlands." *British Journal of Criminology* 44 (1): 66–91.

United Nations Office on Drugs and Crime. 2014. "Crime and Criminal Justice Statistics." May 15. https://www.unodc.org/unodc/en/data-and-analysis/statistics/crime.html.

Van Praag, Bernard M. S., and Barbara E. Baarsma. 2005. "Using Happiness Surveys to Value Intangibles: The Case of Airport Noise*." *The Economic Journal* 115 (500): 224–46.

Velasco, Andres, and Cristobal Huneeus. 2012. *Contra la Desigualdad: El Empleo es la Clave*. Penguin Random House Grupo Editorial Chile.

Wang, Fahui, and W. William Minor. 2002. "Where the Jobs Are: Employment Access and Crime Patterns in Cleveland." *Annals of the Association of American Geographers* 92 (3): 435–50.

Welch, William J. 1990. "Construction of Permutation Tests." *Journal of the American Statistical Association* 85 (411): 693–98.

Wener, Richard E., Gary W. Evans, Donald Phillips, and Natasha Nadler. 2003. "Running for the 7:45: The Effects of Public Transit Improvements on Commuter Stress." *Transportation* 30 (2): 203–20.

White, R. Clyde. 1931. "The Relation of Felonies to Environmental Factors in Indianapolis." *Social Forces* 10: 498.

World Bank. 2014. "World Development Indicators Database." http://data.worldbank.org/indicator/SI.POV.GINI.

Zenou, Yves. 2000. "Urban Unemployment, Agglomeration and Transportation Policies." *Journal of Public Economics* 77 (1): 97–133.

List of Appendices

Appendix 1: Sources for the Gini coefficient and harmonisation of the data

1. Sources

Data of the Gini coefficient for the UK, US, OECD, Chile 2006, 2009, 2011, Mexico 2000, 2004, 2008, 2010, and 2012 come from OECD (2014a). The rest of the data for Chile and Mexico come from the Socio-Economic Database for Latin America and the Caribbean 'SEDLAC' (2014a)

2. Harmonisation of the data for the Gini coefficient

The SEDLAC data for the Gini coefficient has data for some years of Chile and Mexico's Gini coefficient that is not in the OECD data. Both datasets explain in their notes that they use the same calculation for income in the Gini coefficient: household disposable equivalised income post-taxes and transfers. However, the Gini coefficients were n(that were did not appear in the OECD was not exactly the same in the OECD and SEDLAC datasets. Hence, before merging the information for Chile and Mexico from SEDLAC, I scaled the data in SEDLAC adding to it the average difference in each country between the data in both datasets. These average differences are small and do not change the trends in income per capita or inequality for Chile or Mexico.

Appendix 2: Municipalities surveyed in the 1996, 2001, 2006 CASEN panel survey

Chile's 1996, 2001, 2006 CASEN Panel Survey is a follow up survey of the 1996 Casen survey. The 1996 Casen survey selected all municipalities in Chile with more than 40,000 inhabitants and randomly otherwise. Hence, the municipalities in Santiago included in the 1996 CASEN survey are: Calera de Tango, Cerrillos, Cerro Navia, Colina, Conchalí, Curacaví, El Bosque, Estación Central, Independencia, Isla de Maipo, La Cisterna, La Florida, La Granja, La Pintana, La Reina, Las Condes, Lo Barnechea, Lo Espejo, Lo Prado, Macul, Maipú, María Pinto, Melipilla, Ñuñoa, Paine, Pedro Aguirre Cerda, Peñaflor, Peñalolén, Providencia, Pudahuel, Puente Alto, Quinta Normal, Recoleta, Renca, San Bernardo, San Miguel, San Ramón, Santiago, and Talagante. This excludes the municipalities of Huechuraba, Pedro Aguirre Cerda, Quilicura, San Joaquín and Vitacura (Ministerio de Planificación 2005).

Appendix 3: Construction of the index of economic, social and cultural status (ESCS).

According to PISA (2013), 'The PISA index of economic, social and cultural status (ESCS) was derived from the following three indices: highest occupational status of parents (HISEI), highest educational level of parents in years of education according to [the International Standard Classification of Education] ISCED […], and home possessions […].

The index of home possessions […] comprises all items on the indices of [family wealth[15] …], [cultural possessions[16] …] and [home educational resources[17] …], as well as books in the home recoded into a four-level categorical variable (0-10 books, 11-25 or 26-100 books, 101-200 or 201‑500 books, more than 500 books).

The PISA index of economic, social and cultural status (ESCS) was derived from a principal component analysis of standardised variables (each variable has an OECD mean of zero and a standard deviation of one), taking the factor scores for the first principal component as measures of the PISA index of economic, social and cultural status. ' (p. 200).

[15] 'The *index of family wealth* […] is based on students' responses on whether they had the following at home: a room of their own, a link to the Internet, a dishwasher (treated as a country-specific item), a DVD player, and three other country-specific items […]; and their responses on the number of cellular phones, televisions, computers, cars and the number of rooms with a bath or shower' (PISA 2013, 201).

[16] 'The *index of cultural possessions* […] is based on students' responses to whether they had the following at home: classic literature, books of poetry and works of art' (PISA 2013, 201).

[17] The *index of home educational resources* […] is based on the items measuring the existence of educational resources at home including a desk and a quiet place to study, a computer that students can use for schoolwork, educational software, books to help with students' school work, technical reference books and a dictionary' (PISA 2013, 201).

Appendix 4: Imputation of socioeconomic variables in the 2004 SIMCE dataset

The missing values in the 2004 SIMCE dataset are as follows: household income (10.5 per cent), maternal level of education (34.6 per cent), paternal level of education (35.4 per cent), last grade completed by the student's mother in her highest level of education (34.6 per cent) and last grade completed by the student's father in his highest level of education (35.4 per cent).

The steps I carried in the imputation of missing data were as follows. First, in cases where the father's level of education was non-missing, I imputed the mother's (father's) level of education with the level of education of the father (mother). Second, in the remaining missing values, I imputed the level of education of the mother (father) with the median level of education of the mothers (fathers) of the cohort mates in the student's same school. In addition, I also imputed the missing values of household income values with the median category of income in the students' school. The theoretical basis for the imputations in the second step is the abundant evidence that schools in Chile are highly homogeneous in households' socioeconomic characteristics (Mizala, Romaguera, and Urquiola 2007). Third, I imputed the missing values in maternal (paternal) last completed grade in her (his) highest educational level with the paternal (maternal) last grade in his (her) highest level of education. After this imputation process, the missing values decreased to 0.0 per cent in household income, maternal level of education, and paternal level of education, and to 28.9 per cent in the mothers and fathers' last completed year in the highest educational level. Fourth, I created a new category for all the missing values in mothers and fathers last grade in their highest educational level. The aim of this last step is not dropping out of the sample individuals with the latter missing value. If I omit the fourth step, the map in Fig 0.21 does not change.

Appendix 5: Tables on why and how does school–subway network distance matter.

Table A5.1
The effect of school–subway distance reduction on the probability of remaining in high school: nonlinear models

Dependent variable: student remains in high school	(1) Basic model	(2) As (1) plus school covariates	(3) As (2), plus heterogeneity in school–subway distance	(4) As (3), plus spatial controls
0-km distance reduction (reference category)	0	0		
0 km< distance reduction ≤ 1.6 km	–0.0870**	–0.0126		
	(0.0437)	(0.0477)		
1.6 km< distance reduction ≤ 2.3 km	–0.132***	0.0618***		
	(0.0356)	(0.0227)		
2.3 km< distance reduction ≤ 4.7 km	–0.0824*	0.00930		
	(0.0433)	(0.0311)		
4.7 km< distance reduction ≤ 10.7 km	–0.166***	–0.0388		
	(0.0430)	(0.0312)		
School–subway distance ≤ 2 km				
0 km distance reduction (ref. category)			0	0
0 km< distance reduction ≤ 1.6 km			0.0582*	0.165***
			(0.0346)	(0.0515)
1.6 km< distance reduction ≤ 2.3 km			0.0490*	0.107*
			(0.0271)	(0.0605)
2.3 km< distance reduction ≤ 4.7 km			0.0270	0.133*
			(0.0407)	(0.0679)
4.7 km< distance reduction ≤ 10.7 km			–0.00263	0.120
			(0.0431)	(0.0797)
School–subway distance > 2 km				
0 km distance reduction			–0.0163	0.204
			(0.0315)	(0.133)
0 km< distance reduction ≤ 1.6 km			–0.155	0.00855
			(0.104)	(0.0686)
1.6 km< distance reduction ≤ 2.3 km			0.0951**	0.170***
			(0.0409)	(0.0572)
2.3 km< distance reduction ≤ 4.7 km			–0.0152	0.0378
			(0.0441)	(0.0655)
4.7 km< distance reduction ≤ 10.7 km			–0.0739*	0.0352
			(0.0422)	(0.0802)
Number of students in same school and grade in 2004 (log)		0.102***	0.104***	0.106***
		(0.0197)	(0.0195)	(0.0196)
Individual score in language, maths, natural and social science in 2004 fixed effects	No	Yes	Yes	Yes
Household income fixed effects	No	Yes	Yes	Yes
School type of administration fixed effects	No	Yes	Yes	No
Municipality x Type of administration fixed effects	No	No	No	Yes
Proximity to the old subway network fixed effects	No	No	No	Yes
Observations	93,798	83,668	83,668	83,668

Notes: See notes in Table 2. Individual-level probit regressions. Dependent variable: whether students who took the test in eighth grade also took the test in tenth grade. Robust standard errors in parentheses clustered at the school level. *** p<0.01, ** p<0.05, * p<0.1.

Table A5.2

The effect of school–subway distance reduction on the probability of remaining in the same school: nonlinear models

Dependent variable: student remains in same school	(1) Basic model	(2) As (1) plus school covariates	(3) As (2), plus heterogeneity in school–subway distance	(4) As (3), plus spatial controls
0-km distance reduction (reference category)	0	0		
0 km< distance reduction ≤ 1.6 km	-0.365***	-0.243***		
	(0.0825)	(0.0743)		
1.6 km< distance reduction ≤ 2.3 km	-0.515***	-0.170**		
	(0.0986)	(0.0701)		
2.3 km< distance reduction ≤ 4.7 km	-0.146*	0.00315		
	(0.0878)	(0.0589)		
4.7 km< distance reduction ≤ 10.7 km	-0.395***	-0.105		
	(0.0858)	(0.0707)		
School–subway distance > 2 km				
0-km distance reduction (reference category)			0	0
0 km< distance reduction ≤ 1.6 km			-0.164**	-0.188
			(0.0778)	(0.126)
1.6 km< distance reduction ≤ 2.3 km			-0.144*	-0.315**
			(0.0852)	(0.159)
2.3 km< distance reduction ≤ 4.7 km			0.0977	0.126
			(0.0771)	(0.149)
4.7 km< distance reduction ≤ 10.7 km			0.122	0.202
			(0.0806)	(0.180)
School–subway distance ≤ 2 km				
0 km distance reduction | distance > 2 km			0.147**	-0.337
			(0.0659)	(0.211)
0 km< distance reduction ≤ 1.6 km			-0.197	-0.549***
			(0.142)	(0.194)
1.6 km< distance reduction ≤ 2.3 km			0.0622	-0.130
			(0.0956)	(0.145)
2.3 km< distance reduction ≤ 4.7 km			0.0466	-0.113
			(0.0806)	(0.149)
4.7 km< distance reduction ≤ 10.7 km			-0.138	-0.0738
			(0.0937)	(0.181)
Number of students in same school and grade in 2004 (log)		0.196***	0.209***	0.143***
		(0.0356)	(0.0336)	(0.0315)
Individual score in language, maths, natural and social science in 2004 fixed effects	No	Yes	Yes	Yes
Household income fixed effects	No	Yes	Yes	Yes
Municipality x Type of administration fixed effects	No	No	No	Yes
Proximity to the old subway network fixed effects	No	No	No	Yes
School type of administration fixed effects	No	Yes	Yes	No
Observations	47,849	41,348	41,348	41,283

Notes: See notes in Table 2. Individual-level probit regressions. Dependent variable: whether students who took the 2004 test in eighth grade were in the same school in 2006 in tenth grade. Sample restricted to students whose schools had both primary and secondary levels. *** p<0.01, ** p<0.05, * p<0.1.

Appendix 6: Construction of crime variables

I constructed the crime variables in the following way. First, I identified burglary by selecting all robbery ('robo') and larceny ('hurto') in households ('domicilio particular'). Second, I identified larceny in the public space by selecting all larceny in the public space ('via publica'). Third, I identified robbery in the public space by selecting all robbery in the public space. Fourth, I identified domestic violence by selecting all domestic violence reports ('Violencia Intrafamiliar'), homicides ('Homicidio') and injuries ('Lesiones') where there was no specific amount stolen ('aval_bien' equals to 'n/a' or 'Sin avaluo'). Hence, in this last variable construction, I assumed that any injuries inflicted at home where there was no theft was an act of domestic violence. Finally, I identified injuries in the public space by selecting all injuries, homicides and rapes ('Violacion') in the public space.

Appendix 7: Definition of Santiago's urban area

The urban area of Santiago includes the following boroughs: Cerrillos, Cerro Navia, Conchalí, El Bosque, Estacion Central, Huechuraba, Independencia, La Cisterna, La Florida, La Granja, La Pintana, La Reina, Las Condes, Lo Barnechea, Lo Espejo, Lo Prado, Macul, Maipú, Ñuñoa, Pedro Aguirre Cerda, Peñalolén, Providencia, Pudahuel, Puente Alto, Quilicura, Quinta Normal, Recoleta, Renca, San Bernardo, San Joaquín, San Miguel, San Ramón, Santiago, and Vitacura.

Appendix 8: The effect of municipality–subway distance reduction on labour market outcomes: unweighted sample

Table A8.1
The effect of municipality–subway distance reduction on employment status using an unweighted sample: nonlinear models

Dependent variable: 2006–2001 employment status	(1) All individuals	(2) Women	(3) Men
Post-treatment municipality–subway distance ≤ 1 km			
1 km< distance reduction	3.596*	7.898***	-1.352
	(2.048)	(2.722)	(2.756)
0 km< distance reduction ≤ 1 km	-6.253**	-10.09*	-1.203
	(2.696)	(5.375)	(3.213)
0-km distance reduction	-3.437	-0.863	-8.599***
	(2.083)	(2.875)	(2.908)
Post-treatment municipality–subway distance > 1 km			
1 km< distance reduction	1.412	7.932**	-6.789**
	(2.536)	(3.783)	(3.113)
0 km< distance reduction ≤ 1 km	-2.957	0.721	-7.395***
	(2.242)	(3.788)	(2.236)
0-km distance reduction (reference category)	0	0	0
	(0)	(0)	(0)
Observations	2,453	1,361	1,092
R-squared	0.354	0.327	0.449

Notes: Sample constrained to sample of specifications generating Table 4.3. Remaining notes, as for Table 4.2. *** p<0.01, ** p<0.05, * p<0.1.

Table A8.2
The effect of municipality–subway distance reduction on hours of work using an unweighted sample: nonlinear models

Dependent variable: change in monthly hours of work 2001 to 2006	(1) All individuals	(2) Women	(3) Men	(4) As in (1) restricting sample to employed in both periods
Post-treatment municipality–subway distance ≤ 1 km				
1 km< distance reduction	10.50	23.48***	-5.203	13.81*
	(6.506)	(7.220)	(7.548)	(7.010)
0 km< distance reduction ≤ 1 km	1.636	-2.092	5.428	7.706
	(7.809)	(12.62)	(6.562)	(10.70)
0-km distance reduction	-1.344	10.50	-28.60**	16.14
	(8.192)	(9.251)	(10.64)	(14.18)
Post-treatment municipality–subway distance > 1 km				
1 km< distance reduction	-0.605	10.42	-15.23	0.794
	(6.772)	(8.224)	(9.797)	(6.844)
0 km< distance reduction ≤ 1 km	-2.318	7.018	-18.24**	11.08*
	(6.244)	(7.490)	(6.950)	(5.836)
0-km distance reduction (reference category)	0	0	0	0
	(0)	(0)	(0)	(0)
Observations	2,078	1,210	868	744
R-squared	0.267	0.259	0.340	0.112

Notes: As for Table A8.1. *** p<0.01, ** p<0.05, * p<0.1.

Table A8.3
The effect of municipality–subway distance reduction on individual labour earnings using an unweighted sample: nonlinear models

Dependent variable: change in monthly individual labour earnings 2001 to 2006 (in 2001 US$)	(1) All individuals	(2) Women	(3) Men
Post-treatment municipality–subway distance ≤ 1 km			
1 km< distance reduction	-35.02***	-41.58**	-37.68**
	(11.48)	(15.98)	(18.29)
0 km< distance reduction ≤ 1 km	-16.57	-29.47*	-3.766
	(19.16)	(16.26)	(29.76)
0-km distance reduction	-11.99	16.21	-49.73
	(21.04)	(27.68)	(31.70)
Post-treatment municipality–subway distance > 1 km			
1 km< distance reduction	0.554	10.27	-3.472
	(17.96)	(20.31)	(28.17)
0 km< distance reduction ≤ 1 km	-4.373	-14.95	11.13
	(16.69)	(15.36)	(25.19)
0-km distance reduction (reference category)	0	0	0
	(0)	(0)	(0)
Observations	2,464	1,366	1,098
R-squared	0.067	0.093	0.101

Notes: As for Table A8.1. *** p<0.01, ** p<0.05, * p<0.1.

Appendix 9: Balancing test for the placebo experiment in Chapter 4

Table A9

Descriptive statistics—means and standard deviations for individuals in Santiago in the pre and post-placebo periods (1996 and 2001 respectively)

	(1) Entire population	(2) Treated population	(3) Control population	(4) Diff. (2)–(3) (s.e.)
Share of each group in the entire population	100%	2.4%	11.6%	
Predetermined covariates (1996)				
Years of schooling	9.459***	9.277***	8.536***	0.741
	(0.178)	(0.365)	(0.612)	(0.712)
Age	41.87***	44.11***	42.88***	1.231
	(0.605)	(2.665)	(1.553)	(3.084)
Female	0.541***	0.626***	0.564***	0.0620
	(0.0127)	(0.0482)	(0.0260)	(0.0548)
Number of rooms	2.645***	3.278***	2.755***	0.523*
	(0.0746)	(0.257)	(0.160)	(0.302)
Employment rates				
1996	0.627***	0.491***	0.676***	-0.185**
	(0.0167)	(0.0596)	(0.0415)	(0.0726)
2001	0.572***	0.457***	0.590***	-0.133*
	(0.0172)	(0.0523)	(0.0498)	(0.0722)
Hours of work per month				
1996	113.6***	92.40***	126.0***	-33.64**
	(3.243)	(11.57)	(8.092)	(14.12)
2001	83.63***	72.00***	79.62***	-21.09
	(3.462)	(13.30)	(10.61)	(13.93)
Monthly labour earnings (2001 US$)				
1996	215.6***	160.1***	241.6***	-81.57
	(18.16)	(22.29)	(48.33)	(53.22)
2001	185.6***	245.7***	167.4***	78.36
	(12.21)	(88.48)	(36.78)	(95.82)
Observations	2,303	83	325	
Subpopulation size	3,124,023	73,785	361,109	

Notes: Individuals in the treated sample resided in municipalities that experienced a distance reduction to the subway network in 2005 greater than one kilometre and ended up nearer than one kilometre from the subway network. Individuals in the control sample resided in municipalities that did not experience a distance reduction to the subway network in 2005 and in both periods were farther than one kilometre from the subway network. The sample is restricted to working-age population (15 years and older in 2000) who responded to both waves of the Casen Panel Survey and were not full-time students in 1996. All observations are weighted by their longitudinal weights. *** p<0.01, ** p<0.05, * p<0.1.

Appendix 10: Main specifications from Chapter 4 using two kilometres as distance threshold from the subway network when allowing a heterogeneous effect of school–subway distance

Table A10.1
The effect of municipality–subway distance reduction on employment status using a distance threshold of two kilometres: linear models

Dependent variable. Columns (1) through (3): employment status in 2001; columns (4) through (6): 2006–2001 employment status	(1)	(2)	(3)	(4)	(5)	(6)
	Cross-section association			Individual fixed effects		
	Basic model	As (1) plus predetermined covariates	As (2), plus heterogeneity in school-subway distance	Basic model	As (4) plus predetermined covariates	As (4), plus heterogeneity in school-subway distance
Proximity to the nearest subway station (km)	0.0884 (0.116)	-0.167 (0.116)		0.572 (0.492)	0.299 (0.694)	
Proximity to the nearest subway station (km) | distance ≤ 2 km			0.139 (0.129)			0.232 (0.790)
Proximity to the nearest subway station (km) | distance > 2 km			-0.146 (0.113)			0.467 (1.245)
Control variables (2001)	No	Yes	Yes	No	Yes	Yes
Observations	2,511	2,464	2,464	2,500	2,453	2,453
R-squared	0.000	0.966	0.966	0.000	0.362	0.362

Notes: As for Table 4.2. *** p<0.01, ** p<0.05, * p<0.1.

Table A10.2
The effect of municipality–subway distance reduction on employment status using a distance threshold of two kilometres: nonlinear models

Dependent variable: change in employment status 2001 to 2006	(1) All individuals	(2) Women	(3) Men
Post-treatment municipality–subway distance ≤ 2 km			
2 km< distance reduction	2.722	7.173	-2.204
	(4.138)	(5.761)	(4.764)
0 km< distance reduction ≤ 2 km	-1.301	-0.290	-1.569
	(4.275)	(6.145)	(5.010)
0-km distance reduction	4.430	5.416	-3.164
	(3.929)	(5.327)	(4.647)
Post-treatment municipality–subway distance > 2 km			
2 km< distance reduction	1.039	3.168	-1.087
	(3.056)	(5.234)	(3.601)
0 km< distance reduction ≤ 2 km	-5.269*	-6.271	-5.324
	(2.877)	(4.921)	(3.673)
0-km distance reduction (reference category)	0	0	0
	(0)	(0)	(0)
Observations	2,453	1,361	1,092
R-squared	0.366	0.341	0.502

Notes: As for Table 4.2. *** p<0.01, ** p<0.05, * p<0.1

Table A10.3
The effect of municipality–subway distance reduction on hours of work using a distance threshold of two kilometres: nonlinear models

Dependent variable: change in monthly hours of work 2001 to 2006	(1) All individuals	(2) Women	(3) Men	(4) As in (1) restricting sample to employed in both periods
Post-treatment municipality–subway distance ≤ 2 km				
2 km< distance reduction	8.793	23.73	-1.289	10.96
	(10.37)	(14.07)	(11.61)	(11.62)
0 km< distance reduction ≤ 2 km	10.92	24.54*	-4.643	18.92
	(8.357)	(13.70)	(7.277)	(13.78)
0-km distance reduction	22.08	27.78	-7.728	31.89
	(15.05)	(20.00)	(10.94)	(22.14)
Post-treatment municipality–subway distance > 2 km				
1 km< distance reduction	6.284	11.88	1.037	-4.971
	(7.153)	(10.41)	(10.28)	(8.750)
0 km< distance reduction ≤ 2 km	-6.702	-2.736	-11.63	9.406
	(5.478)	(9.276)	(6.991)	(9.391)
0-km distance reduction (reference category)	0	0	0	0
	(0)	(0)	(0)	(0)
Observations	2,078	1,210	868	744
R-squared	0.273	0.290	0.391	0.206

*Notes: As for Table 4.2. *** p<0.01, ** p<0.05, * p<0.1.*

Table A10.4

The effect of municipality–subway distance reduction on individual income from work using a distance threshold of two kilometres: nonlinear models

Dependent variable: change in monthly individual labour earnings 2001 to 2006 (in 2001 US$)	(1) All individuals	(2) Women	(3) Men
Post-treatment municipality–subway distance ≤ 2 km			
2 km< distance reduction	-33.32	47.05	-105.8*
	(36.14)	(39.05)	(58.12)
0 km< distance reduction ≤ 2 km	15.21	11.01	-1.094
	(36.93)	(41.53)	(60.88)
0-km distance reduction	32.77	8.794	40.67
	(52.60)	(34.91)	(93.22)
Post-treatment municipality–subway distance > 2 km			
2 km< distance reduction	-4.268	-66.18	91.78*
	(25.66)	(32.03)	(33.04)
0 km< distance reduction ≤ 2 km	-7.275	-42.81	32.47
	(25.66)	(32.03)	(33.04)
0-km distance reduction (reference category)	0	0	0
	(0)	(0)	(0)
Observations	2,464	1,366	1,098
R-squared	0.136	0.270	0.187

Notes: As for Table 4.2. *** p<0.01, ** p<0.05, * p<0.1.