The Anticipated Capitalization Effect of a New Metro Line on Housing Prices

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Abstract

Housing units with closer access to public transportation enjoy a higher market value than those with similar characteristics but poorer access. This difference can be explained by the lower cost of transport to the main workplaces and shopping areas in town. For this reason, investments in public transport infrastructure, such as building a new metro line, are capitalized totally or partially into land and housing prices.

This work empirically analyses the degree of capitalization into housing prices of the benefits of the new Line 4 of the Santiago metro system, which began operating in December 2005. We focus on anticipated capitalization into housing prices at the moment construction of Line 4 was announced and at the moment information on the basic engineering project was unveiled, identifying the location of the future stations.

We use a unique database containing all home buying and selling transactions in the Greater Santiago area between December 2000 and March 2004. The results show that the average apartment price rose between 4.1% and 7.9% after construction was announced and between 3.9% and 5.4% after the location of the stations was identified. This increase was not distributed evenly, but depended on the distance from the apartment to the nearest station.

An indirect effect of this kind of capitalization is that property tax collection will increase if property is reappraised following the price rise. This effect is not negligible in magnitude and could represent 11% to 17% of investment in the new metro line. This raises an interesting discussion on how the metro network extension is financed.

Key Words: Metro, apartment prices, anticipated capitalization

Classification JEL: H54, R21, R53

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1. Introduction

Investing in public transport infrastructure has a strong influence on urban development patterns and on the spatial distribution of property development. Building or improving highways and mass public transport not only reduces transport costs and traffic congestion in urban areas, therefore facilitating the efficient operation of cities, but also affects land use patterns and property values.

The impact of investments in public transport facilities is, therefore, not limited to public transport and their effect on housing markets might be particularly important, for example, in cities such as Beijing and London which, in preparation for the Olympic Games, are expanding their transportation systems significantly. In Beijing a new subway line started operating in 2007 and three more lines will be operating in 2008. In London, a high speed line between St Pancras and mainland Europe began operating in November 2007, the Docklands Light Rail network is being extended by more than 25%, a new line from Stratford International to Canning Town will be operational by mid 2010, and a 2.5 kilometres extension under the River Thames from King George V to Woolwich Arsenal will be ready by 2012. Even tough the goal of these investments is to meet the transport demand generated by the Games, the improved accessibility will also affect land and housing markets and uncovering these effects might have important implications for public policy.

Economic theory predicts that the benefits of the different facilities and public transport services will be capitalized totally or in part into land and housing prices (Henneberry (1998), Oakland (1987), Rubinfeld (1987)). Despite these predictions, no consistent relationship between proximity to transport lines and property prices has been demonstrated. For instance, Debrezion, Pels, and Rietveld (2003), Dewees (1976), Grass (1992), Bajic (1983), Voith (1991), and Al-Mosaind, Dueker, and Strathman (1993) all find positive effects for trains and subways in different cities of the United States and Canada. In contrast, Dornbusch (1975), Armstrong (1994), and Bowes and Ihlanfeldt (2001) show negative effects for trains. Little empirical evidence is available on the anticipated effects of building public infrastructure. Some of this evidence shows a degree of significant capitalization before a new facility or transport system starts operating (McMillen and McDonald, 2004; Damm et al., 1980; McDonald and Osuji, 1995), whereas Gatzlaff and Smith (1993) find no evidence concerning the effects of the announcement of the new train system in Miami.

In the case of Santiago, Chile, the metro system constitutes one of the country's most important investments in public transport infrastructure. The government decided to enlarge the system significantly in 2001, extending two of the existing lines and building a new one. This study draws on the Santiago experience to identify the degree of capitalization of a new metro line into the house prices of the suburbs the new line will serve. We use a unique data base and a methodology that combines hedonic regressions with an average treatment effects estimation to analyse the degree of capitalization of access to the new Santiago metro line into house prices. Because the new line started operating in December 2005, the estimated effect on property prices corresponds to the capitalization of the present value of future benefits granted by access to the soon-to-be-operating new line, based on house sales from December 2000 to March 2004.

The results show an important effect of anticipated capitalization of the new Line 4 of the Santiago metro. The average price of apartments rose between 4.1% and 7.9% after construction was announced and between 3.9% and 5.4% after the basic engineering project showing the location of the stations was unveiled. The degree of capitalization is not homogeneous; but depends, as expected, on the distance to the nearest station. For an apartment located within 200 metres of a station, the average price increase is 7.4% after the announcement of construction and 5.3% after the unveiling of the basic engineering project, while for a flat located between 600 and 800 metres away, the average price rise is 5% and 3.8%, respectively.

The content of this paper is organized as follows. Section 2 provides a brief description of the Santiago metro system, particularly with respect to the new Line 4 construction. Section 3 introduces a simple capitalization model. Section 4 discusses identifying the metro system's effect on house prices, and section 5 describes the data used. Section 7 presents and discusses the empirical results. Our conclusions are outlined in section 8.

2. The Santiago Metro System and the New Line 4

In 1969, the Santiago metro network was designed as the central axis of the city transport system. The master plan included seven lines that would be built following demand evolution. In 1975, the first section, Moneda–San Pablo, began operating. Line 1 was later extended to Escuela Militar in 1980. Line 2 opened in 1987 and Line 5 in 1997. These three lines encompass 40.2 kilometres of railways and 52 stations. In 2004, an average 866,700 daily trips were registered on weekdays.

In May 2001, the government announced a new investment plan to solve the urban public transport problems in the city of Santiago. This plan, called Transantiago, implied a reorganization of public transport through an integrated transit system with new buses, separate bus lanes, and the metro network.[1] The metro thus played a primary role as articulator of the new public transport system, and the Transantiago plan involved correspondingly important investments to improve and extend the metro network. These investments consisted in extending Lines 2 and 5 and building Line 4. The extensions of Lines 2 and 5 have been operating since 2004; Line 4 was completed in March 2006.

The new Line 4 (Tobalaba–Vespucio–Puente Alto) encompasses 33 kilometres of railways and is divided into a main line and a secondary section. The main section covers 24.4 kilometres and has 21 stations, while the secondary section runs 8.7 kilometres, with six stations.[2] Demand projections prior to construction estimated an increase in the average daily circulation flow of about 324,000 passengers—that is, 34.7% of the traffic at the time.

3. Public Goods, Transportation Costs, and Housing Prices

The characteristics associated with a housing unit and its location determine the price a prospective buyer is willing to pay for it. Location bears a fundamental effect for two reasons:

[1] The government's objective with the Transantiago plan is to generate an efficient public transport system that reduces traffic jams and air pollution. Additionally, integrating all the available means of public transport should improve the quality of service.

[2] The total project, including the extensions of Lines 2 and 5, encompassed 38.6 kilometres and 33 stations.

access to public goods and transportation costs. With regard to the former, location determines the level of the local public goods the residents can consume.[3] The market price of a housing unit thus reflects the marginal value to be paid by all potential purchasers of units located in an area with access to a set of public goods (Yinger, 1982; Rubinfeld, 1987). The degree of heterogeneity in preferences for local public goods determines the degree of capitalization, but empirical evidence shows that its average value tends to capitalize significantly on housing prices.[4] Transportation costs, in turn, are also an important factor in house prices, following the characteristics of a given unit and access to public goods. The market price thus reflects the time and distance to the main job markets and shopping areas in a city (Von Thünen, 1863; Alonso, 1964; Mills, 1967; Muth, 1969).

The new Line 4 is a semi-public good that reduces the cost of travelling to the main workplaces and shopping centres of Santiago. We would therefore expect the planning and construction of the new line to generate a rise in housing demand in the areas close to new Line 4 stations. Because the land supply in the relevant area is fixed in the long term, an increase in demand should be reflected in an increase in land prices and housing units located near Line 4 stations. This increase would depend on the distance of the different housing units and properties from the new metro stations.

3.1. Simple Capitalization Model

This section introduces a simple model, adapted from Alonso (1964), to illustrate the consumer location decision explicitly in terms of the metro network. The problem facing each consumer is to maximize his/her utility V, which depends on the size and location of the housing unit and all other consumption goods, subject to a budget constraint that explicitly considers transportation costs and its effects on housing prices. This maximization can be expressed as follows:

[3] The reason is that enjoyment of local public goods is coupled with consumption of land, of which there might be a fixed supply. This creates the possibility of capitalization and that local public goods might be "located" in space, which implies that capitalization differs within jurisdictions as well as between jurisdictions (Oakland (1987)).

[4] See Gramlich and Rubinfeld (1982).

$$\max_{m,d,x} V(m,d,x) \text{ subject to}$$

$$Y = x + P(d)m + T(d), \tag{1}$$

where m is the average property size, d is the distance from the property to the nearest metro station, x is a compound good made up of all the other staples an individual consumes, $P(d)$ is the price per square metre of the property, $T(d)$ is the transport cost function, and Y is consumer's income. The inclusion of distance in an individual's utility function captures the disutility (leisure) for the consumer to reach the nearest metro station.

We assume that function V is continuous, twice differentiable, and strictly quasi-concave, increasing in m and x and decreasing in d. Additionally, $\partial P(d)/\partial d<0$ and $\partial T(d)/\partial d>0$. The first-order conditions for this maximization problem are the following:

$$V_m - \lambda P(d) = 0\,; \tag{2}$$

$$V_d - \lambda\left(P_d m + T_d\right) = 0\,; \tag{3}$$

$$V_x - \lambda = 0\,; \tag{4}$$

$$Y - x - P(d)m - T(d) = 0\,. \tag{5}$$

One of the equilibrium location conditions can be obtained from equations (2) and (4),:

$$\frac{V_x}{V_m} = \frac{1}{P(d)}. \tag{6}$$

This first equilibrium condition establishes that the marginal ratio the consumer is willing to accept to substitute consumption of square metres of property, m, with consumption of other goods is equal to the relative price. Relative prices depend on the distance to the transport service under study.

A second equilibrium condition is obtained from equations (3) and (4):

$$P_d m = -\left(T_d - \frac{V_d}{V_x}\right). \quad (7)$$

This second condition establishes that the marginal willingness to pay per square metre of property to increase distance decreases as marginal transport costs increase and rise as marginal disutility rises.

This simple model shows that, from a theoretical viewpoint, house prices should be negatively related to the distance to the nearest metro station. This price/distance relationship is not necessarily monotonically decreasing, since the metro station may have two possible impacts. On the one hand, the availability of a new means of transport produces a direct positive effect by reducing transport costs for neighbourhood residents; on the other, the metro station generates a host of indirect effects, such as increased circulation of people, a higher noise level, and more commercial activities. The net impact of this host of indirect effects is ambiguous because some of them may have a positive impact on the price of the housing units nearest to the station, while others may have a negative effect. Consequently, the relationship between house prices and the distance to the nearest metro station may have non-linearities, and some of the function components may even be increasing.

Although this simple model offers an empirically testable forecast with respect to the impact of distance to the metro station on property values, it does not consider a number of other factors that also affect housing prices and are included in consumer decisions. Empirical evidence shows that other important determinants of house prices include the housing unit characteristics (number of rooms, age, square metres, and so forth), the neighbourhood characteristics (delinquency rate, average income, the quality of schooling in the area, etc.), property taxes, and the local supply of public goods (such as garbage collection, police patrolling, and hospitals).[5]

In broad terms, the house price equation to be estimated is as follows:

$$\log P_{it} = \alpha + \beta X_{it} + \gamma L_{it} + \delta D_{it} + \eta_i + \mu_t + \varepsilon_{it} \quad (8)$$

where the dependent variable, P_{it}, is the selling property price of house i at time t; X_{it} is the

[5] See, for example, Vessali, (1996); Gibbons and Machin (2005).

housing unit structural assets vector (including size, number of bathrooms, bedrooms, and so forth); L_{it} is the vector reflecting the neighbourhood and location features other than access to mass transit (such as public goods, green areas, shops, schools, and clinics); D_{it} is a vector for the relevant variables related to access; η is a location fixed effect, μ is a time fixed effect (monthly and annual in the empirical analysis), and ε_{it} is the idiosyncratic error capturing unobserved determinants of housing prices.

The estimation of equation (8) is equivalent to a hedonic price regression (Rosen, 1974; Bartik, 1987; Freeman, 1979), which captures the implicit prices of housing attributes, i.e. how the price a housing unit varies with the set of characteristics it possesses (Sheppard (1999)).[6]

4. Identification

A hedonic price estimation such as equation (8) allows us to estimate consumers' marginal value of access to the metro station. For this purpose, it is sufficient for the vector *D* to be defined as the distance to or the time it takes to reach the nearest station. Access capitalization can then be identified by estimating how house prices vary as distance to the station increases or by estimating the difference between house prices within the range of the metro stations and those outside the range. This exercise should show the impact of metro lines already in operation.

The purpose of this study, however, is to estimate the capitalization of Line 4 before it began operating. Specifically, we want to estimate the degree of anticipated capitalization into house prices of the future benefits of the new line. To this effect, we identify six different stages in the development of Line 4.

1. General layout ($t = 1$): The general layout of the metro network has been known since 1969, but consumers face uncertainty with regard to when new investments will be made and whether the original layout will be followed.

[6] The estimated coefficients may be interpreted as the willingness to pay for a marginal increase of said characteristic.

2. Specific announcement ($t = 2$): In May 2001, the government announced the extension of Lines 2 and 5 and the creation of the new Line 4 to Puente Alto. The location of the stations was not immediately known, however, and the implementation of the project was uncertain given that financing was still being discussed.
3. Basic engineering project ($t = 3$): The location of the future Line 4 metro stations was revealed in December 2001.
4. Start of construction ($t = 4$): Construction of Plaza Puente Alto Station began in July 2002.
5. Opening ($t = 5$): Part of Line 4 was opened in December 2005, and it was operating fully as of March 2006.
6. Operating consolidation ($t = 6$): In the first few months in operation, consumers collect additional information concerning the quality of service, frequency, and prices.

If consumers have rational expectations, the capitalization of the benefits of the new Line 4 should take place at the moment the construction is announced. However, the degree of house price adjustments also depends on the expected risk of the construction not occurring and of uncertainty concerning the location of the stations.

To discuss identification of the impact of the metro system on housing prices, we focus on one stage, namely, the announcement of the construction of the new metro line. We define the $t\text{–}1$ period as the ex ante situation before announcement and t as the ex post period. If, in effect, some capitalization did occur, and controlling for all other relevant factors, then the price of a housing unit, i, should increase from P_{it-1} at $t\text{–}1$ to P_{it} at t. To quantify the effect of building the metro line on a given property price, we would need to compare the new price with the price that would have pertained if the metro line had not been built—that is, we need to imagine a counterfactual situation.[7] As it is not possible to observe the same housing unit under both conditions, we have to rely on comparisons between different housing units and estimate average "treatment" effects (Angrist and Imbens (1994)). One alternative is to compare property prices after the announcement of line 4 with property prices before the announcement for a broadly equivalent group of properties. This comparison, controlling for the effect of observable housing and

[7] See Rubin (1974); Rosenbaum and Rubin (1983); Angrist, Imbens, and Rubin (1996); Heckman, Ichimura, and Todd (1997).

location characteristics, leads to the following before-after estimator:[8]

$$\log P_{it} = \alpha + \beta X_{it} + \gamma L_{it} + \delta D_{it} + \theta T_t + \eta_i + \mu_t + \varepsilon_{it} \tag{9}$$

where T_t is a dummy variable equal to 1 after the "treatment" (announcement or basic engineering of new line 4) and 0 before. The identifying assumption for this estimator is that the difference between the true post-treatment counterfactual and their pre-treatment property prices averages out to zero across all housing units affected by the announcement of the new metro line 4. Basically, the before-after estimator assumes that the unobservables are of two types: those specific to a housing unit and fixed over time and those specific to a housing unit but not fixed over time (transitory effects). If the assumption is satisfied, this approach does not require longitudinal data, but can be implemented instead with repeated cross-section data so long as at least one cross-section is from a pre-treatment period.

A second alternative is to use a "natural experiment" approach (Blundell and MaCurdy (1999)) and compare a before-after estimate of property prices between two different housing groups, one whose prices are affected by the new metro line and one whose prices are unaffected by the new metro line. The identifying assumption is that the average change in property prices if line 4 would not have been built would be the same for affected and unaffected housing units.[9] For implementing this approach we define two housing groups: properties located within a 1 kilometre radio from the closest metro station and properties located outside that radio. The chosen distance is based on the results of the Origin-Destination Survey for Santiago in 2001 that showed that around 90% of metro demand for each station comes from that distance, a result that was also confirmed to us by managers of the metro company. The comparison of these two housing groups leads to the following difference-in difference estimator:[10]

$$\log P_{it} = \alpha + \beta X_{it} + \gamma L_{it} + \delta D_{it} + \theta_1 T_t + \theta_2 T_t D_{1000} + \eta_i + \mu_t + \varepsilon_{it} \tag{10}$$

[8] Heneberry (1998), Lin and Hwang (2004), Laakso (1992), and McDonald and Osuji (1995) use this type of estimation to analyze transport influences on property prices.

[9] This is basically an assumption of common time effects across groups (Blundell, Duncan, and Meghir (1998)).

[10] Bajic (1983), Dewees (1976), Gatzlaff and Smith (1993), Lee (1973), and McMillen and McDonald (2004), although these works differ concerning model specification, in general the idea is to compare changes in house prices in the area within reach of the metro impact with the changes in the control housing units not in the scope of the metro impact.

where D_{1000} is a dummy variable equal to 1 if the housing unit is within 1000 meters of its closest metro station and 0 otherwise and θ_2 captures the impact of the new metro line on housing prices.

We interpret this estimator, after modifying the hedonic regression specified in equation (7), as the average change in the marginal value of the distance from the housing unit to the metro station with respect to the average change in the marginal value of units outside the metro range.

As it was previously mentioned, the error ε_{it} in equations (9) and (10) captures unobserved determinants of housing prices. Some unobserved effects are price variations related to the bargaining process and location characteristics for which there are no data available, such as crime rates or pollution. In the specific case of Santiago, also the investment in intra-city motorways might have also affected housing prices in a different way. All these unobserved effects must be uncorrelated with the explanatory variables to avoid any potential bias in the estimators. For this reason, in the empirical analysis is important to control for as many housing and location characteristics as possible. Additionally, the inclusion of location and time dummies can account for some of these unobserved factors.

5. Data

Our empirical analysis draws on data from the Real Estate Registry of Santiago.[11] This unique database contains all real estate transactions made in 25 communities in the Greater Santiago area between December 2000 and March 2004. Each observation contains the selling price, a set of variables describing the physical attributes of the property, and the geographical location (east-north coordinates).

The available information on the physical attributes of housing units is very limited. We therefore decided to use only the data on apartment transactions, which include more detailed information on the characteristics. There are 20,900 recorded transactions in the municipalities of Providencia, Las Condes, La Reina, Peñalolén, Macul, Ñuñoa, and La Florida over this period.

[11] The *Conservador de Bienes Raíces de Santiago* records all transactions involving housing, offices, and land in 25 communities out of 35 in the Greater Santiago area. This database was kindly provided by Mapcity S.A.

For each apartment, we calculated the distance to each of the 44 metro stations (of which 19 pertain to Lines 1 and 5 and 25 to the future Line 4). This involved two steps: first, we used Mapcity (a digital map of Santiago) to georeference the metro stations corresponding to Lines 1, 4, and 5; second, we calculated the Euclidian distance (*d*) between each apartment and the metro stations, as illustrated in figure 1.[12] Of the 20,900 total apartments in the database, there are 6,907 units for which the shortest distance to a station corresponds to the new Line 4.

Figure 1. The Euclidean Distance from a Housing Unit to a Metro station.

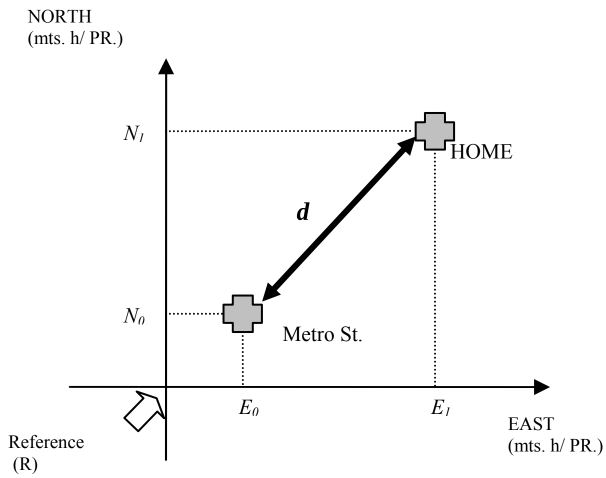


Table 1 shows the summary statistics of the variables used in the estimation. The dependent variable is the logarithm of the apartment price measured in UF.[13] Our explanatory variables fall into three groups of variables. The first set of variables covers the structural characteristics of each apartment, including the size in square metres, the number of bedrooms and bathrooms, whether there is a basement or elevator in the building, whether the building includes parking, whether the apartment is new versus previously owned, whether the building is

[12] The location process is simply a means of to assigning a pair of east-north coordinates to each observation. The distance from the housing unit to the metro station is defined as $d = \sqrt{(E_1 - E_0)^2 - (N_1 - N_0)^2}$.

[13] The *Unidad de Fomento* (UF) is an inflation-indexed unit of account authorized by the Central Bank of Chile and used extensively throughout the economy. In September 2005, one UF equalled Ch$17,700 or US$32.80.

located on a side street or a main avenue, and whether it is eligible for the DFL2 tax benefits.[14] The second set of variables captures access to public and semi-public goods. In addition to distance to the metro station, we used the procedure described above to calculate the distance from the apartment to the nearest school, public hospital, private clinic, and green area. The communities in our sample have a total of 582 schools, 8 hospitals, 52 clinics and 756 existing green areas. Finally, the third set of variables consists of a series dummies equivalent to fixed effects for community, month, and year. We also included dummies to help isolate the value of access to the stations over different periods at different distances, in order to capture the degree of anticipated capitalization of the metro into housing prices.

Table 1. Summary Statistics

Variable	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
Price (UFs)	2,688	1,387	201	29,804
Size (square metres)	84	32	16	508
New unit	0.57	0.50	0	1
DFL2 tax benefits	0.05	0.21	0	1
No. bedrooms	2.66	0.81	1.00	5
No. bathrooms	2	1	1	4
Parking	0.59	0.49	0	1
Basement	0.69	0.46	0	1
Elevator	0.71	0.45	0	1
Located on a side street	0.59	0.49	0	1
Located on an avenue	0.38	0.49	0	1
Distance to nearest clinic (metres)	948	963	9	4,992
Distance to nearest hospital (metres)	2,656	1,111	386	6,482
Distance to nearest school (metres)	252	165	6	1,020
Distance to nearest green area (metres)	295	195	15	1,251
Change in housing stock	28,337	1,716	24,046	31,903
Distance to nearest metro station (metres)	1,516	1,113	8	4,939
Announcement	0.82	0.28	0	1
Basic engineering	0.66	0.43	0	1
D1000 (dummy)	0.58	0.44	0	1

The variable *Announcement*, a dummy equal to 1 after May 2001 and 0 before, captures the change in average housing prices as a result of the announcement of construction of the new metro line, and the expected sign is positive. As mentioned earlier, the different stations had not

[14] Decree Law 2 of 1959 (DFL2) establishes that income earned from the rental of houses and apartments smaller than 140 square metres is exempt from income tax and other taxes, and income from the sale of such properties is exempt from the capital gains tax. Additionally, property taxes are reduced by 50% for the first ten years.

yet been defined when the construction of Line 4 was announced. Moreover, price adjustments in the property market probably lag the announcement because of house-searching costs and the need for consumers to match sellers. A considerable degree of capitalization may therefore have occurred after the announcement. The variable *Basic engineering*, a dummy equal to 1 after December 2001 and 0 before, captures the effects of the release of additional information on the engineering project, including station location, seven months after the announcement.

We also interact the variables *Announcement* and *Basic engineering* with the variable *Distance to the nearest metro station* to capture the change in the price of apartments located near a station as a result of the announcements of construction and station location. Although we expect property values to decrease as the distance to a station increases, prices may also fall for apartment units that are vary close to a station, given that they will be subject to more noise and a greater circulation of people and shopping (Dueker, Chen, and Rufolo, 1998).

A potential problem with these two interacted variables is that the estimations also consider the distance of apartments for which the metro system is irrelevant. For example, the construction announcement or station location is unlikely to affect the price of a flat located four kilometres from the nearest station. The expected bias derived from including distance for those units is downward—that is, the estimated coefficients may show a lower property value rate as the distance to the metro station increases. To eliminate this potential bias, we interact *Announcement* and *Distance to the nearest metro station* with the *D1000* dummy variable, which distinguishes between apartments within a 1,000 metre range of each station and apartments farther away.[15] This last variable is a difference-in-difference estimator, such the one mentioned in section 4.

6. Results

This section reports the results of estimating equations (8) and (9) to determine the degree of capitalization after the construction of the new line was announced and after the basic

[15] Metro S.A. estimates that around 50–60% of the demand is captured within 500 metres of the station and 80–90% within 1,000 metres.

engineering project was unveiled. We consider four separate specifications in each case. Model 1 estimates equation (8) using either the *Announcement* or *Basic Engineering* dummy to capture the impact of the metro line on apartment prices. Model (2) includes the distance to the nearest station interacted with the corresponding treatment dummy (*Announcement* and *Basic engineering*). Model 3 also includes the interaction between the treatment dummy and the distance squared, to capture non-linearities. Finally, model 4 estimates equation (9), including for this purpose the interaction of the treatment dummy with a dummy equal to one if the apartment is located less than 1,000 metres from the station, and zero otherwise.

The specification of the first three models helps capture the effects of the construction announcement (or the release of information on the basic engineering project) on housing prices, depending on the distance between the housing units and the closest metro station. The fourth model specification helps determine the degree of capitalization in apartments located within the scope of direct impact of the new metro line.

The results related to the characteristics of the units generally have the expected signs and are quite robust concerning the different specifications. The estimated coefficients for number of bedrooms, number of bathrooms, basement, elevator, and parking are all positive and statistically significant. An additional bedroom and an extra bathroom are associated, on average, with price increases of 379 UFs and 488 UFs, respectively. Similarly, a basement, an elevator, and parking raise the price of an apartment, on average, by 260 UFs, 95 UFs, and 64 UFs, respectively.

The effect of the DFL2 tax benefit is positive and statistically significant. A housing unit eligible for the tax benefit is sold, on average, at a price of 224 UFs higher.

The results for access to some public goods are not altogether satisfactory. The estimated coefficient for the variable measuring distance to the nearest hospital is negative as expected, but only statistically significant in models (1) and (4). In the case of the variable measuring distance to the nearest clinic, the coefficient is statistically significant but positive in all models. Given that the quality of medicine and service in clinics is much superior than in hospitals, this result might just reflect ha value of having a clinic in the community. The coefficient for distance to the nearest school is not statistically significant in all models. As in the case of clinics, one possible explanation is that the quality of service is more important than the distance to the school. The coefficient for the distance to the closest green area is significant only in model (3) but positive, which is contrary to what we expected. The regression does not control for the quality and size of the green area, so a possible explanation in this case is that consumers may prefer a better, larger, more distant green area to a smaller, but closer one. For some of the communities in the sample, green areas are associated with high crime.

Finally, a change in the housing stock has a negative effect on apartment prices but is statistically not significant. This variable should reflect the impact of increased supply on the market equilibrium price.

6.1. Capitalization following the Announcement of Construction

Table 2 shows the results of the estimation using the construction announcement as the treatment variable. The coefficient of *Announcement* is positive and statistically significant in all four specifications. The estimator point for *Announcement* is between 100 UFs and 191 UFs, depending on the specification, which is equivalent to an average apartment value appreciation of 4.2% to 7.9%.

The interaction of the variables *Announcement* and *Distance to the nearest metro station* has a negative impact on apartment prices and is statistically significant, showing an uneven distribution of anticipated capitalization of metro access. Following theoretical predictions, increases in apartment value decrease as the distance to the nearest station grows. The estimated coefficient shows that the metro system's impact falls by 0.071 UF for each additional metre from the nearest station. However, when non-linearities are considered the results show that the distribution of the positive impact on apartment prices has a humped shape. In this case the impact increases by 0.067 UF and then falls by 0.00004 UF.

Table 2. Estimation for the Announcement of the Construction of Line 4

Dependent Variable ln(price)	(1)		(2)		(3)		(4)	
No. bedrooms	0.155586	*	0.156593	*	0.158479	*	0.155576	*
	0.005955		0.005921		0.005930		0.005919	
No. bathrooms	0.202492	*	0.201544	*	0.200276	*	0.202010	*
	0.008549		0.008463		0.008477		0.008468	
Age	-0.021502	*	-0.021918	*	-0.022006	*	-0.021813	*
	0.000599		0.000604		0.000605		0.000603	
DFL2 tax benefit	0.092111	*	0.091439	*	0.096342	*	0.089929	*
	0.018011		0.017973		0.017857		0.018063	
Parking	0.028654	*	0.026421	*	0.024103	*	0.027625	*
	0.008179		0.008160		0.008146		0.008145	
Basement	0.108816	*	0.107342	*	0.104274	*	0.108833	*
	0.008922		0.008853		0.008826		0.008878	
Elevator	0.039339	*	0.036916	*	0.030510	*	0.036197	*
	0.008822		0.008765		0.008842		0.008761	
Apartments by Floor	-0.006534	*	-0.006576	*	-0.006289	*	-0.006555	*
	0.000580		0.000573		0.000582		0.000565	
Located on an avenue	0.079048	*	0.071937	*	0.056287	*	0.077777	*
	0.024515		0.024464		0.024615		0.024439	
Located on a side street	0.085665	*	0.074154	*	0.061933	*	0.078222	*
	0.024453		0.024509		0.024584		0.024474	
Distance to nearest school	0.000034		0.000037		0.000045		0.000006	
	0.000029		0.000029		0.000029		0.000029	
Distance to nearest hospital	-0.000032	*	-0.000004		0.000005		-0.000014	*
	0.000005		0.000007		0.000007		0.000006	
Distance to nearest clinic	0.000040	*	0.000042	*	0.000049	*	0.000038	*
	0.000009		0.000009		0.000008		0.000009	
Distance to nearest green area	0.000016		0.000021		0.000042	**	0.000018	
	0.000025		0.000025		0.000025		0.000025	
Change in Housing Stock	-0.000003		-0.000003		-0.000003		-0.000003	
	0.000002		0.000002		0.000002		0.000002	
Announcement	0.041566	*	0.079084	*	0.051036	*	0.013000	
	0.018094		0.019353		0.020085		0.018677	
Announcement*Distance			-0.000029	*	0.000028	*		
			0.000005		0.000012			
Announcement*Distance ^{2}					-1.59E-08	*		
					3.01E-09			
Announcement*D1000							0.049720	*
							0.008429	
Constant	6.773321	*	6.687733	*	6.647344	*	6.734431	*
	0.091788		0.091870		0.091551		0.092193	
Community Dummies	yes		yes		yes		yes	
Monthly Dummies	yes		yes		yes		yes	
Annual Dummies	yes		yes		yes		yes	
R-squared	0.7023		0.7037		0.7053		0.7039	
F	434.35		426.33		413.07		431.11	
Observations	6804		6804		6804		6804	

Model 4 provides some interesting results. Unlike the other three models, it includes the dummy variable D1000 interacted with the variable *Announcement*. As described earlier, this variable distinguishes units within a 1,000 metre range of a metro station. Because the strongest impact occurs within this range, the variable helps distinguish the group of units with treatment from the group without treatment. It is thus a difference-in-differences estimator. The results for this model show a capitalization of 120.5 UFs in apartment values following the announcement of the construction of the new line.

6.2. Capitalization following the Release of Information on the Basic Engineering Project

Table 3 shows the results of the estimation using the release of information on the basic engineering project as the treatment variable. The most pertinent piece of information involved is the location of the metro stations.

The coefficient of the *Basic engineering* variable is positive and statistically significant. The estimator point reflects a capitalization of between 74 UFs and 132 UFs. This is equivalent to an average increase of 3.9% to 5.4%, which is lower than the estimated increase following the announcement of the construction of the new line.

As with the former results, the degree of capitalization depends importantly on the apartment's distance to the nearest station. The interaction of the *Basic engineering* and *Distance* variables captures that effect. The estimated coefficient is negative and statistically significant, and it reflects a lower price of 0.04 UF for each additional metre from the closest metro station. Again, when non-linearities are considered the results show a humped distribution of the positive impact of the new metro line on apartment prices.

Table 3. Estimation for the Release of Information on the Basic Engineering Project

Dependent Variable ln(price)	(1)		(2)		(3)		(4)	
No. bedrooms	0,155867	*	0,156509	*	0,157177	*	0,156167	*
	0,005944		0,005926		0,005937		0,005911	
No. bathrooms	0,202054	*	0,201652	*	0,201015	*	0,201726	*
	0,008542		0,008488		0,008505		0,008470	
Age	-0,021560	*	-0,021736	*	-0,021723	*	-0,021808	*
	0,000598		0,000603		0,000604		0,000603	
DFL2 tax benefit	0,077514	*	0,078910	*	0,080841	*	0,077944	*
	0,016085		0,015993		0,015936		0,016054	
Parking	0,029855	*	0,028704	*	0,027737	*	0,029036	*
	0,008169		0,008173		0,008179		0,008151	
Basement	0,107521	*	0,107604	*	0,106671	*	0,108280	*
	0,008914		0,008908		0,008915		0,008894	
Elevator	0,040118	*	0,039070	*	0,037261	*	0,036957	*
	0,008794		0,008784		0,008821		0,008776	
Apartments by Floor	-0,006552	*	-0,006530	*	-0,006371	*	-0,006546	*
	0,000580		0,000577		0,000586		0,000569	
Located on an avenue	0,078139	*	0,075154	*	0,068259	*	0,078391	*
	0,024502		0,024518		0,024757		0,024460	
Located on a side street	0,085751	*	0,080546	*	0,075610	*	0,081488	*
	0,024453		0,024550		0,024698		0,024473	
Distance to nearest school	0,000032		0,000034		0,000037		0,000011	
	0,000029		0,000029		0,000029		0,000029	
Distance to nearest hospital	-0,000032	*	-0,000019	*	-0,000016	*	-0,000020	*
	0,000005		0,000006		0,000006		0,000006	
Distance to nearest clinic	0,000041	*	0,000042	*	0,000046	*	0,000039	*
	0,000009		0,000009		0,000008		0,000009	
Distance to nearest green area	0,000017		0,000018		0,000027		0,000018	
	0,000025		0,000025		0,000025		0,000025	
Change in Housing Stock	-0,000003		-0,000002		-0,000002		-0,000002	
	0,000002		0,000002		0,000002		0,000002	
Basic Engineering	0,030593	**	0,054579	*	0,038746	**	0,009329	
	0,018097		0,019607		0,020741		0,018235	
Basic Engineering *Distance			-0,000017	*	0,000013			
			0,000005		0,000013			
Basic Engineering *Distance2					-8,14E-09	*		
					3,36E-09			
Basic Engineering *D1000							0,043018	*
							0,008780	
Constant	6,768847	*	6,719979	*	6,701893	*	6,735071	*
	0,091754		0,091601		0,091229		0,092085	
Community Dummies	yes		yes		yes		yes	
Monthly Dummies	yes		yes		yes		yes	
Annual Dummies	yes		yes		yes		yes	
R-squared	0,7022		0,7027		0,703		0,7033	
F	434,02		425,31		411,27		429,99	
Observations	6804		6804		6804		6804	

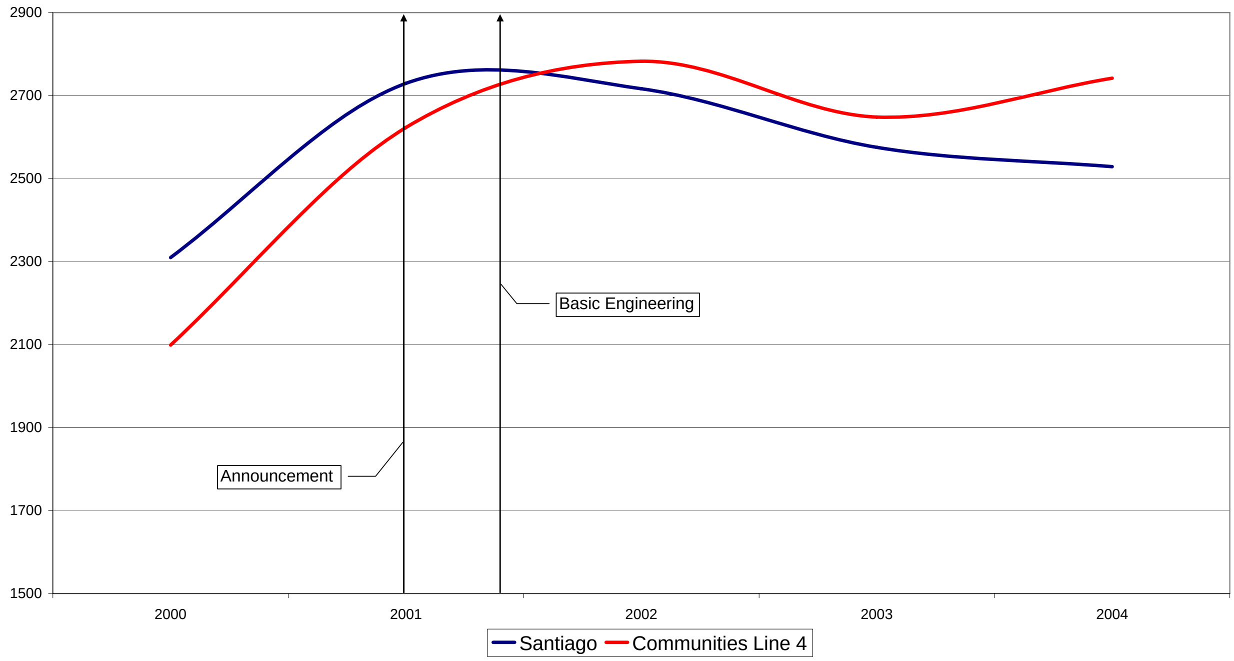
The results in tables 2 and 3 are strongly robust with regard to alternative specifications of the models and more flexible structural errors. We included for example time trends, but they were never significant and the rest of the coefficients did not change. We also used seemingly unrelated regressions (SUR) to estimate a community equations system, to rule out possible residual correlation problems between municipalities.[16] The Breush-Pagan test for independence of equations did not reject the hypothesis that the variance-covariance matrix of the system is diagonal.

One potential concern with the results is related to identification. As it was explained before, a consistent estimator is obtained under the assumptions of common time effects and fixed unobserved factor across treatment and control areas. These assumptions are not testable, but it is possible to check two issues to find some support for them. First, if prices evolution in treatment and control areas followed a parallel path before treatment; and in fact, they did. As can be seen in Figure 2, before "treatment" the evolution of housing prices in communities near the new metro line was not different than the evolution of housing prices in the rest of the city of Santiago. Second, if observable housing characteristics were similar before and after treatment; and hey also did.[17]

[16] For example, prices in neighbouring communities may display a degree of spatial correlation.

[17] There are no statistical differences before and after the treatment for the variables *age*, *number of bedrooms*, *number of bathrooms*, *elevator*, *parking*, and *basement* (for example, the average number of bedrooms is 2.61 before treatment and 2.60 after treatment; the average number of bathrooms is 2.06 before treatment and 2.02 after treatment).

Figure 2: Average Apartments Price (UF)



An additional concern with the results is the potential bias due to unobserved effects on housing prices due to the construction of intra-city motorways. Even though it is impossible to disentangle the effects of the motorways from the effects of the new metro line (at least with the data available), it is possible to check the robustness of our results. For this purpose, all models were run again dropping the observations of all the communities affected by the new intra-city motorways and the results were quite robust to this sample change.[18]

It is also possible that the results identify different densities more than capitalization of the new metro line. To explore this possibility, we included in all models a variable measuring population density (inhabitants by block) and the results did not change.

Finally, table 4 shows the average percent change in apartment values as a result of the

[18] For example, the coefficient for *Announcement* in model (1) was 0.040 (compared to 0.042) and the coefficient for *Announcement* interacted with D1000 was 0.046 (compared to 0.049). The R^2 was slightly lower: 0.68 8compared to 0.70).

announcements of the construction of the new line and the basic engineering project, based on the distance to the nearest station. The average impact on the price of apartments within range of the new Line 4 ranges from 3.8% to 7.4%, depending on the distance to the nearest station. While this increase is important in magnitude, the impact is probably higher for two reasons. First, our estimations are based on data prior to the opening of the new metro line. Conversations with real estate agents indicate that selling prices rose further once the system was actually operating. Second, supporting theoretical and empirical evidence suggests that the benefits of the expanded metro system are also capitalized into the wages of the people living in communities served by the metro (Roback, 1980 and 1982; Blomquist, Berger, and Hoenh, 1988; Gyourko and Tracy, 1989 and 1991). The estimated capitalization into housing may thus underestimate the total capitalization of the benefits of the new Line 4.

Table 4. Increase in Average Apartment Prices, by Distance to Metro Stations

Percent

	Distance to nearest station (metres)				
Timing of increase	*0–200*	*201–400*	*401–600*	*601–800*	*801–1000*
Announcement of construction	7.4	6.8	6.1	5.7	5.0
Basic engineering	5.2	4.8	4.5	4.0	3.8

6.3. Fiscal Effect of Capitalization

One of the most important indirect effects that metro capitalization into house prices may have is an increase in property taxes. For this effect to actually occur, the Internal Revenue Service must reassess properties in the communities where the new line will be operating.

The change in tax collection (ΔR) may be calculated as:

$$\Delta R = \sum_{i=1}^{n} t_i \Delta B_i \ , \tag{11}$$

where ΔB stands for the change in the tax base and t_i is the tax rate, which is a function of property value.[19]

Using the results from these estimations and equation (11), we estimated the potential changes in the tax base (that is, the property tax appraisal) and in non-agricultural land payments. For this exercise, we considered only the 3,131 apartments located within 1,000 metres of the nearest new Line 4 station.

Table 5 presents the main results for each of the four models estimated. We assume that the rise in the tax appraisal of each apartment increases proportionately with the capitalization following the announcement of the basic engineering project. In case I, we assume that the increase in the appraisal is independent of the distance between the apartment and the nearest metro station. In case II, we assume that the increase in the appraisal considers the degree of capitalization and thus depends on the distance between the apartment and the nearest station.

Table 5. Change in Property Tax Collection

Percent

Case	*(1)*	*(2)*	*(3)*	*(4)*	*Change in sample mean*
Case I: independent of distance	5.65%	8.61%	8.51%	6.83%	7.40%
Case II: dependent on distance	5.10%	6.37%	4.80%	5.86%	5.53%

As the table shows, capitalization of the metro benefits into house prices may bring about a rise of 5.7% to 8.6% in apartment tax payments in the sample if the appraisal does not take into

[19] Non-agricultural areas zoned for housing enjoy a property tax exemption of Ch$10,878,522 as of 1 January 2005. For properties appraised above that amount, the excess value is taxed at 1.2% per year when the appraised value of the eligible property does not exceed Ch$37,526,739 or 1.4% per year when the appraised value is over that amount.

account the distance to the metro station. The increase is 5.1% to 6.4%, if the appraisal reflects the lower capitalization of apartments farther from the metro stations.

The estimated increase in property tax collection represents between 1.9% and 4.2% of the cost of investing in Line 4. Our calculation of the estimated impact on tax collection is based on a sample of around 10% of all the apartments located within the range of the new Line 4 stations. If the impact for the remaining 90% of the population (33,911 total apartments according to the 2002 census) is similar, on average, then the increase in total collection would be between 51,698 UFs and 116,748 UFs in present value. This represents 11.3% to 16.6% of the cost of investing in the metro system.[20]

This estimated increase in tax collection is a lower bound, for various reasons. First, the estimation assumes that new development projects will not be incorporated over the next 40 years. Second, we do not consider the 86,691 new housing units in the 1,000 metre range of all Line 4 stations in the sample communities. Third, we do not include the increased tax collection stemming from higher housing prices in La Granja, San Ramón, La Pintana, La Cisterna, and El Bosque (communities that are also within the range of Line 4 stations). Finally, we do not estimate the increase in tax collection from business licenses.

7. Conclusions

Investing in public transport infrastructure contributes to reducing travelling time and modifies consumer location preferences. In the medium or long run, urban conformation also changes. Santiago's metro system is one of the country's most important investments in public transport infrastructure. In 2001, the government decided to enlarge the metro coverage considerably by extending Lines 2 and 5 and building a new Line 4. The construction of this new line has had important effects for the city and has given way to different positive externalities. Policymakers need to evaluate these effects in terms of urban planning, public transport, and fiscal policies. Additionally, the expansion project sent signals to the private sector, generating

[20] We are assuming a 40 year useful life for the metro trains (with 100 years for infrastructure and rails) and an 8% discount rate.

important impacts in terms of housing development projects.

This work has made use of a unique database to study one of the many effects of building a new metro line: namely, the appreciation of property served by the new line. In particular, we used a methodology that combines hedonic regressions and the estimation of average treatment effects to estimate the degree of capitalization of metro access into house prices. Based on the availability of data, we focused our estimations on the anticipated capitalization of the benefits of the new line into apartment prices.

Our results indicate that anticipated capitalization had a very important effect on property values. The average price of an apartment rose between 4.1% and 7.9% after the construction was announced and between 3.9% and 5.4% after the basic engineering project (including the location of the stations) was unveiled. The degree of capitalization depends on the distance to the nearest metro station, decreasing at a rate of 0.07 UF to 0.04 UF for each additional metre from the closest station.

Finally, we also estimated the increase in property tax collection stemming from the increased property values. This income should be an important consideration in future extensions of the metro system. If the state, which indeed makes the investment, can capture the property value increase that results from building a new line, the resulting revenues can contribute to financing part of the extensions.

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