UNIVERSIDAD DE CHILE
FACULTAD DE CIENCIAS FÍSICAS Y MATEMÁTICAS
DEPARTAMENTO DE INGENIERÍA INDUSTRIAL

ESTIMATING THE HOUSING INVESTMENT EXTERNALITIES EFFECTS OF A PUBLIC HOUSING PROGRAM IN CHILE

TESIS PARA OPTAR AL GRADO DE MAGÍSTER EN ECONOMÍA APLICADA

MEMORIA PARA OPTAR AL TÍTULO DE INGENIERO CIVIL INDUSTRIAL

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Este trabajo ha sido parcialmente financiado por:
Instituto Milenio de Imperfecciones de Mercado y Políticas Públicas

SANTIAGO DE CHILE
2022

ESTIMACIÓN DE LOS EFECTOS DE EXTERNALIDADES EN LA INVERSIÓN EN VIVIENDA DE UN PROGRAMA DE VIVIENDAS SOCIALES EN CHILE

En esta tesis, estudio los efectos de externalidades de vivienda del DS-49, un programa de viviendas sociales en la Región Metropolitana, Chile. Utilizando una estrategia cuasi-experimental, aprovecho las características y la variación en el tiempo del tratamiento urbano para estimar efectos de externalidades causales en función de la distancia a los proyectos. La estimación en forma reducida de los efectos sugiere que, en promedio, aquellos hogares que están más cerca de los proyectos de viviendas sociales invierten más en mejorar su calidad de vivienda y menos en seguridad, en comparación con quienes que se encuentran más lejos. Sin embargo, este efecto es predominante en hogares con mayores ingresos, mientras que aquellos con menos recursos pueden ser desalentados a invertir. Separo los efectos según el momento de la inaguración del proyecto y discuto sus implicancias. Un cálculo de servilleta para las externalidades de vivienda indica que estas podrían representar un retorno sobre la inversión extra de hasta 5,1 %.

ESTIMATING THE HOUSING INVESTMENT EXTERNALITIES EFFECTS OF A PUBLIC HOUSING PROGRAM IN CHILE

In this thesis project, I study the housing investment externalities effects of the DS-49, a public housing program in RM, Chile. Using a quasi-experimental strategy, I take advantage of the characteristics and time variation of the urban treatment to estimate the causal externalities effects as a function of distance. Reduced form estimation of the effects demonstrates that, on average, households that are closest to the housing projects invest more in housing quality and less in security that those furthest away. However, this effect is predominant in high income households, while those with less resources may be discouraged to invest. I separate the effects by the time of the project's inauguration and discuss its implications. A back-of-the-envelope calculation for housing investment externalities indicate that these could represent an additional return on investment of up to 5.1 %.

Para Nany,
que tu luz me acompañe siempre.

Agradecimientos

A cada una de las personas con quienes compartí en esta etapa universitaria y que dejaron algo en mí.
A mis amigos del colegio, a Los Cracks, Piñas y Los Bakanos y sus primos, en especial a Pipe Sapag, Mata y Chorizo por su apañe.
A mis amigos de Los Milenials y al Flora por todos estos años estudiando como un toro, en especial al Mauro, Hugo, Guille, Javo, MSc PhD(c) Stefan y Diego que apañaron en el Discord durante la pandemia y aportaron de alguna u otra forma al desarrollo de esta tesis.
A la Zumba Flúor Party™, por reinventar el género y choripanes gratis.
A las personas que conocí en los (fallidos) proyectos, en especial a la Carli, Zelada, Isi, don Felipes, Fran, Pau, et al.
A mi grupo de intro a la ingeniería no. No me acuerdo que hicimos, pero ojalá que estén bien.
A mis amigos do Porto con quienes tuve la suerte de topar y a mis roomies Bruninho, Adriel y Alex.
A la gente del Volley, en particular a Dirty Volley por sus cochinaes. Tkms.
A los cabros y cabras de JGM, por acogerme en su equipo y poder levantar la copa de los JOE, simplemente épico.
A Raimundo Undurraga, Juan Escobar y Raphael Bergoeing por sus comentarios y su aporte en mi formación.
A Piero Zanocco por su ayuda y comentarios en los primeros pasos de esta tesis.
A mi familia, tías, primos y abuelos por su cariño durante todos estos años.
A mis hermanas por dejarme ser el mejor hermano que puede existir.
A la Cami por todo su amor en estos casi 4 años, has hecho de estos años los mejores.
A mis padres, por todo su cariño y amor. Gracias por todo lo que han dado y sacrificado por mí. Les debo todo.
Finalmente, agradecer con todo mi corazón a la Nany, quien no alcanzó a estar conmigo en este momento, pero estoy seguro que estaría orgullosa. Un abrazo al cielo ♡.

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Chapter 1

Introduction

Economic development in low and middle-income countries has not only made urban areas grow and become more dense, but has also presented new challenges to public policy-makers to ensure decent housing conditions to all its inhabitants, and also, to make cities less segregated. Urban investment carried out by the governments have had a fundamental role in trying to solve these problems, but the complex interaction between all the agents that inhabit cities makes it difficult to take into account all the possible side effects of these interventions on urban configuration and social welfare.

In Chile, an important part of the urban public expense goes to housing programs. Therefore, it's fundamental to assess the externalities effects produced by public housing investment interventions, not only to take account of the positive or negative impact of the policy on the indirect beneficiaries -which is important because, in general, houses are the main asset hold by households in Chile (Cox et al., 2006 [1])-, but also to formulate and implement cost-efficient programs.

Current available literature suggest that housing investment externalities produced by housing investment are, in general, positive. This is, housing improvements incentive housing investment decisions of surrounding neighbors (Rossi-Hansberg et al., 2010 [2], Helms, 2012 [3], Patacchini & Venanzoni, 2014 [4], among others). Nevertheless, there is little evidence on the Housing externalities effects produced by interventions that, in addition to improving the general perception of quality in neighborhoods, promote social integration.

This thesis-project seeks to contribute in this regard by estimating the housing investment externalities of a public program, called 'Fondo Solidario de Elección de Vivienda D.S. N49' (FSV-DS49), in the Metropolitan Region (RM), Chile, which is a public housing subsidy offered by the Ministerio de Vivienda y Urbanismo (MINVU) that promotes access to home-ownership among low-income households living in a condition of social vulnerability and housing deprivation.

1.1. The FSV-DS49 program

Empirical evidence in RM shows that, in the last 40 years, social disintegration has strongly increased due to the formation of neighborhoods conformed by social housing programs and low-quality buildings in the outskirt of the city of Santiago, which are generally far away from basic services and amenities (Brain, et. al, 2007 [5]). In response to this issue, since 2007, MINVU has incorporated to its objectives, along with ensuring quality house-ownership, particularly for vulnerable families, social integration, aiming to develop housing solutions inserted in consolidated neighborhoods.

The FSV-DS49 is one of the public housing programs carried by the government. It provides a subsidy to low-income vulnerable households to acquire a housing solution. Under this program, eligible households are organized in housing committees and are offered a subsidy of U.F. 400 per household ($\sim$ US$17,000) to finance the construction of a housing project in a given neighborhood of their choice. The location of their house or department is collectively determined according to the preferences of the committees of applicants and through a Sponsoring Entity (SE) that coordinates them.

Households targeted are part of the lowest 40 % of income in the 'Registro Social de Hogares (RHS)[1], and, in order to apply to the subsidy, applicants have to save in a special account a minimum of 10-15 U.F., depending on the their score on the social registry. Once applicants agree and the SE agrees on the location to build the housing project -from a bank of available terrains-, the SE signs a contract with a Real Estate Company stating the norms and deadlines involved in the construction of the housing project. The constructions of dwellings may take from 18 to 36 months. In the period May 2018 - December 2019, MINVU expected that, only in R.M., 7,360 beneficiary households, distributed in 41 FSV-DS49 housing projects across 25 municipalities, got their new residences.

The program host households coming from different socio-economic statuses, moving to neighborhoods that are also diverse between them in dimensions such as housing quality and economic conditions, since the distribution of available land is spread throughout the region.

In our model, housing investment externalities effects will depend on the perceived change of housing quality in the neighborhood, given by the quality of the public housing project and, also, on the characteristics of former inhabits and their houses. The new quality gap produced by the intervention -between the owner's perceived own housing quality and the altered general neighborhood housing quality- will vary depending on every particular project of FSV-D49, so we expect the effects to be heterogeneous at neighborhood-level.

Even though intervened zones are diverse in housing characteristics and quality, projects that are part of FSV-DS49 have a superior quality in comparison to the former houses in the neighborhoods. Furthermore, in general, these housing projects not only increase the average quality of the neighborhood, but also can provide new amenities, such as green areas, playgrounds and public gym equipment to the direct beneficiaries and also for the neighbors, which could enhance social integration.

MINVU creates an open invitation to tender for every single project of the program, so projects may have different architectures and be built by distinct real estate firms, but the bidding bases ensure minimum quality standards for all the projects that are, in most cases, above the standard of former houses in the intervened neighborhoods. Figure 1.1 shows a

[1] When applications are made collectively, at least 70 % of the group has to pertain to the lowest 40 % in order for the group to be eligible for the program.

social housing project from FSV-DS49 developed in 2014[2]

Figure 1.1: 'Conjunto Altos de la Cordillera' social housing project in RM

Specifically, this research project aims to estimate the causal externality effects of the FSV-DS49 program on the housing investment behaviour of the former residents of the intervened neighborhoods who were indirectly exposed to FSV-DS49 projects.

1.2. A quasi-experimental approach

Even though it's not possible to use an experimental strategy to calculate the externalities effects, since the assignment of housing projects to neighborhoods are not random because location is chosen collectively by FSV-DS49 beneficiaries among a bank of available terrains, we take advantage of the characteristics of the implementation of the program, and adopt a quasi-experimental analysis as empirical strategy.

The implementation of this strategy is possible because of the presence of time variation in treatment and that 'treatment' and 'control' groups are comparable before treatment.

During 2017, MINVU approved the initiation of construction activities of FSV-DS49 housing projects, which were planned to be delivered during the period May 2018 - December 2019. Intervention timing is exogenous since the the inauguration of the different projects occurs in different dates by causes that do not depend of the characteristics of the former and incoming neighbors nor the neighborhoods.

On the other hand, we use empirical evidence based on baseline surveys applied to residents living in and out of intervened neighborhoods to demonstrate the validity of our identification assumptions. In particular, we show that, for the universe of FSV-DS49 housing projects to be implemented in the period May 2018 - December 2019 in RM:

1. The variation in timing at which the housing projects are planned to be implemented is orthogonal to the pre-treatment characteristics of both the beneficiaries and existing

[2] 'Conjunto Altos de la Cordillera' is made up of 18 5-story reinforced concrete buildings, each one associated with a stair core for common use. Each apartment has a total surface of 58 mt^2. It has intervened almost 12.000 mt^2 and considers common green areas and municipal equipment for the use of all the neighbors in order to facilitate social integration.

residents of target neighborhoods, i.e., that those who will be treated first in time are statistically comparable to those who will be treated later on, and this is valid for the incoming neighbors (beneficiaries directly affected by the program or 'treatments') as well as for the existing residents (non-beneficiaries indirectly affected by the program or 'internal controls');

2. The pre-treatment characteristics of residents located out of the target neighborhoods but within a radio of 2 kms from them ('pure controls') are statistically comparable to the pre-treatment characteristics of residents of target neighborhoods, and these are also orthogonal to the timing of program implementation; and

3. Within target neighborhoods, the Euclidean distance between project location and the locations of existing residents are orthogonal to their pre-treatment characteristics, i.e., the characteristics of those living relatively close versus relatively far from the project location are statistically comparable ex-ante construction of the housing project.

Surveys are implemented in 2 different periods; in 2018, the Baseline survey, and in 2019, the Follow-Up survey. Thus, in this study, statistically significant causal effects are found using Follow-Up survey by controlling for Baseline outcome variable-levels.

Chapter 2

A Theoretical Model of Housing Externalities

2.1. Basic model

A basic framework that rationalizes the agent's decisions in housing investment is the one proposed by Davis & Ortalo-Magné (2011) [6]. The household problem consists in the maximization of their utility as a function of consumption and housing expenditure. The economy in the model is conformed by I households and N closed neighborhoods, in which each one has a fixed supply of houses H_n.

Formally, the problem of the household i that lives in the neighborhood n, decides the amount of consumption of goods c_i and housing consumption h_{in}, and takes the housing rental prices r_n as given, subject to their budget constraint as a function of their income w_i, is:

$$\max_{c,h} \; c_i^{1-\gamma} h_{in}^{\gamma} \tag{2.1}$$

$$s.t. \quad c_i + r_n h_{in} \leq w_i \tag{2.2}$$

Where γ is exogenous and represents the elasticity of households preferences. In practice, this is estimated as the average proportion of housing expenditure over the average household income $\frac{\bar{h}}{\bar{w}}$.

Definition 1: The equilibrium in this economy is defined as the vector of household's optimal decisions in consumption (goods and housing) $\{c_i\}_{i,..,I}$ and $\{h_{in}\}_{i,..,I}$, such that:

1. The agents maximize their utility. From the first order conditions, for each $i = 1, ..., I$, we have that goods consumption satisfies:

$$c_i^* = (1-\gamma) w_i \tag{2.3}$$

and for housing consumption:

$$h_{in}^* = \gamma w_i / r_n \tag{2.4}$$

2. Market clearance for every neighborhood:

$$N_n h_{in} = H_n \quad \Leftrightarrow \quad N_n > 0 \tag{2.5}$$

where N_n is defined as the total housing supply in the neighborhood n.

The estimation of the Chilean Central Bank (2016) [7] of the parameter γ, that represents the relative importance of the housing consumption over the good's consumption in Chile, corresponds to $\gamma = 0.21$. Clearly, this model only incorporates housing expenditure as the total price paid for the rental of the house, but it does not take into account the value of the physical investment, such as the value of extensions, remodeling, repairs, among others, nor the effects of externalities produced by them. The model proposed in the next section incorporates i) the housing externalities effects in the housing investment and expenditure decisions and ii) the effect of gentrification and housing resignations that externalities effects can cause.

2.2. Model with housing externalities

To underscore the relevance of housing externalities in determining the effects of public housing policies, we develop a one period partial equilibrium model based on the framework proposed by Rossi-Hansberg & Sarte (2012)[3] [8].

Under the same environment as the base model, with given housing rental prices r_n, the agents choose goods consumption c_i and housing consumption h_{in}, which can be separated between housing rental h_{in}^R and housing investment ϕh_i^I, subject to their budget constraint.

The level of investment made by the public housing program in the neighborhood ($\overline{H}$) also affects their consumption and investment behaviour. To model if these externalities effects are supplements (complements) will depend on the sign of the term $\overline{H}_n^d$ in Equation 2.6. If it's positive (negative), then we will assume that this externality effect acts as a supplement (complement), generating a detriment (benefit) in the agent's own housing consumption and, therefore, in their own utility.

The utility function of the household i is therefore defined as[4]:

$$\mathcal{U}_{in} = c_i^{1-\gamma} h_{in}^{\gamma} \equiv c_i^{1-\gamma} (h_{in}^R + \phi h_i^I \pm \overline{H}_n^d)^{\gamma} \tag{2.6}$$

[3] In the model that the authors propose, the housing externalities effects affect the housing investment decisions taken by households as complements. This is, individuals benefit from investment in nearby homes, and therefore they reduce their housing investment decisions, increasing their available income to consume other goods. Given that in this general equilibrium model prices are determined by demand in the neighborhood, then rental prices rise, causing externalities to be capitalized by homeowners, lowering investment in housing quality in comparison to its initial level.

[4] In the utility function, ϕ represents the valuation of the households for durable goods. It is a parameter that differentiates the utility in terms of the nature of the durable goods (h_i^I) and non-durable goods (c_i and h_{in}^R). If we suppose that depreciation does not affect h_i^I and a constant discount rate r, then ϕh_i^I corresponds to the present value of a lifetime amenity with $\phi = 1/r$.

Formally, if the housing externalities act as a complement to housing consumption, the problem that households face is:

$$\max_{c,h}\ c_i^{1-\gamma}(h_{in}^R + \phi h_i^I - \overline{H}_n^d)^\gamma \tag{2.7}$$

subject to:

$$c_i + r_n h_{in}^R + p_n h_i^I \leq w_i \tag{2.8}$$
$$r_n h_i^R = R_{in} \tag{2.9}$$

Where $\overline{H}_n^d \equiv f(h_p, d_{pi}) = \frac{\upsilon}{d_{pi}^\theta} h_p$ is defined as the perception of change of the housing quality of the neighborhood, that depends of the size of the social housing investment in the neighborhood h_p, the distance from the house i to the social housing project p, d_{pi}^θ, and a positive and constant parameter υ. We will assume that $\overline{H}_n^d$ is positive, since, as was mentioned previously, DS-49 public housing program has superior housing quality compared to former residents.

Regarding the constraint budget (2.8), r_n is the housing rental price per mt^2 and p_n is the average price of housing investment per mt^2 built. Equation 2.9 is a constraint that refers to the nature of the good traded in the housing rental market; a house is a non-divisible and a non-tradable good. This means that it's not possible to add 1 extra mt^2 of rented house in the same building, since the rental of a house is offered as a whole. Furthermore, the housing rental service can't be imported to the neighborhood; if a household wants to rent a house outside the neighborhood they have to move out.

Definition 2: The equilibrium in this economy is defined as the vector of household's optimal decisions in consumption (goods and housing) $\{c_i\}_{i,..,I}$ and $\{h_i n\}_{i,..,I}$, such that:

1. The agents maximize their utility. From the first order conditions, for each $i = 1, ..., I$, we have that goods consumption satisfies:

$$c_i^* = (1-\gamma)(w_i - R_{in} - \frac{\phi}{p_n}(\bar{H}_n^d - R_i/r_n)) \tag{2.10}$$

   and for housing investment[5]:

$$\boxed{h_i^{I*} = \frac{(1-\gamma)}{\phi}(\bar{H}_n^d - R_{in}/r_n) + \frac{\gamma}{p_n}(w_i - R_i)} \tag{2.11}$$

2. Market clearance for every neighborhood:

$$N_n h_{in}^R = H_n \quad \Leftrightarrow \quad N_n > 0 \tag{2.12}$$

   where N_n is defined as the total housing supply in the neighborhood n.

From first order conditions of housing investment (Equation 4) it's possible to notice that the perception of housing quality change in the neighborhood $\bar{H}_n^d$ positively affects the

[5] Demonstration can be found in Appendix A.1

housing investment h_i^{I*}. This increase can be rationalized as the effort to fill the housing quality gap, understood as the difference of the perceived quality of the neighborhood and the own produced by the intervention. The reason behind this would be that individuals are adverse to be outside the 'social norm', and therefore, when there's an investment in the neighborhood that increases perceived housing quality of it, individuals are driven to invest in order not to deviate from the norm.

2.3. 2 periods model

In order to calculate the externalities effects over the intervened neighborhoods by the social housing projects, we represent the equilibrium situation in 2 consecutive periods. At time $t = 0$, neighborhood is in equilibrium and without the presence of the public social housing project. At time $t = 1$, the neighborhood is in equilibrium posterior to the intervention. Therefore, based on the optimal housing investment level of the model with externalities for a household (that keeps living in the same neighborhood) the externalities effects for i are given by[6]:

$$\Rightarrow \Delta h_i = \frac{(1-\gamma)}{\phi}\bar{H}_n^d = \frac{(1-\gamma)}{\phi}\frac{\upsilon h_{pn}}{d_{pi}^{\theta}} \tag{2.13}$$

Which are the externalities effects over the decision of housing investment in the household i. Here we assume that the price of housing investment p_n does not vary, because this parameter corresponds to a price of a tradable good in a non-arbitrage environment.

Even though this thesis project doesn't pretend to make a structural estimation, through this model is possible to propose a causal relationship between pubic investment and the effects on housing investment carried out by households. A Montecarlo simulation of housing investment externalities is provided in Appendix B. Reduced form estimation is discussed taking account of this framework in Chapter 4.

[6] Demonstration can be found in Appendix A.2

Chapter 3

Data

During 2017, MINVU approved the initiation of construction activities of 41 FSV-DS49 housing projects distributed in 41 neighborhoods across 25 municipalities of the Metropolitan Region (RM). The approved housing projects hosted a total of 7,360 beneficiary households and were planned to be delivered during the period May 2018 - December 2019. The spatial distribution of the public housing projects is displayed in Figure 3.1. As it is possible to notice from the map, the distribution of the housing projects is spread across all RM, and are built in very dense areas (red dots closest to the city center) and also in the city suburbs (red dots to the west that are furthest from Santiago).

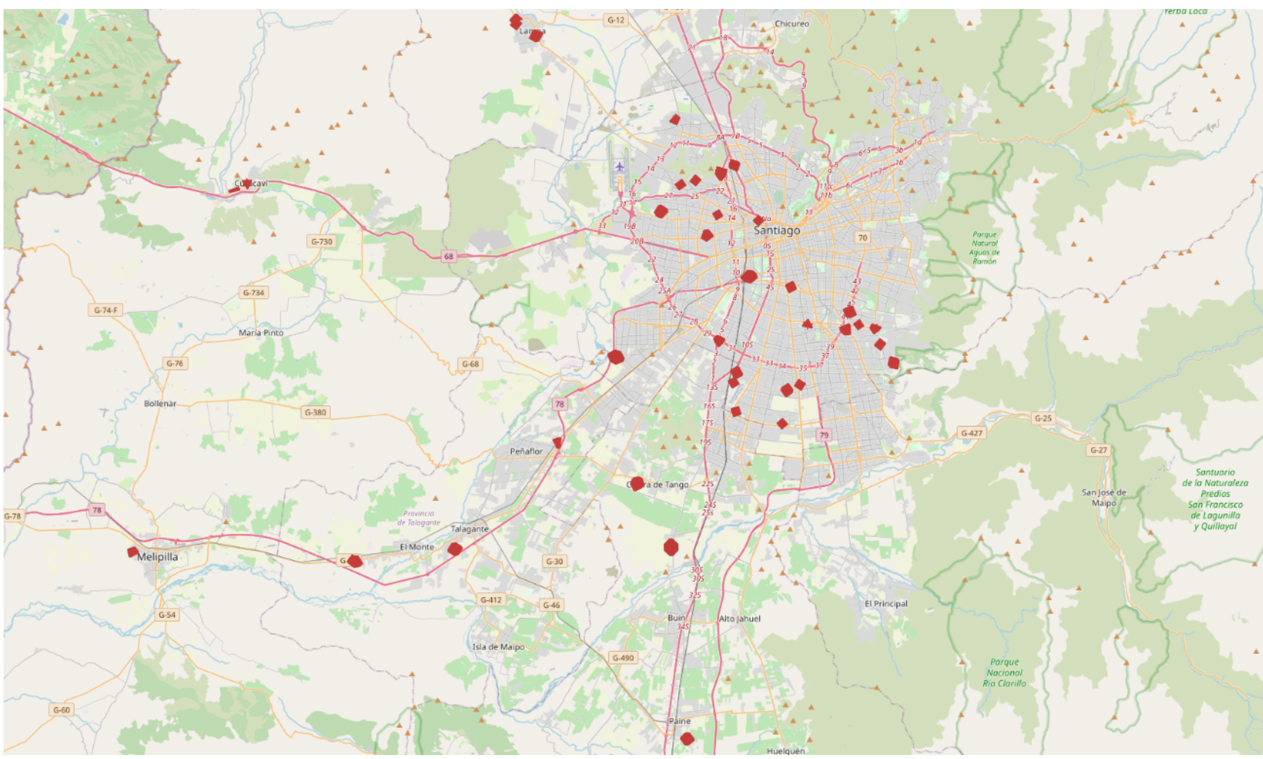

Figure 3.1: Map of Social housing projects distribution across RM (in red).

We utilize the dataset constructed by Undurraga (Working Paper) [9]. Available data consist on two surveys taken in 2018 (Baseline survey) that was performed before the intervention of the program in the neighborhoods, and in 2019 (Follow-Up survey), approximately 1 year after the intervention.

Our sample of study was randomly chosen and consists on 2,162 households residing in the 41 to-be-intervened neighborhoods, all of whom are expected to be indirectly affected by the construction of FSV-DS49 housing projects during the aforementioned period[7]. Information gathered from the survey contains relevant information about household's family characteristics, houses addresses, wages, housing rental expenses, and different measures of perceptions about the social housing intervention.

In Chapter 4, we will take a look at the reduced form results of the externalities effects of the proximity to the social housing projects, using investment in different types of assets and cash invested in these assets as outcome variables. The data used for estimation of the models is retrieved from the section of 'Home Improvements' of the Baseline and Follow-Up survey, presented in Appendix C.3, implemented for 2 different groups of indirectly affected households; Group 1 -households that lived in neighborhoods where the housing project had been inaugurated yet at the time of the Follow-Up survey implementation-, and Group 2 -households that lived in neighborhoods where the housing project had not been inaugurated yet at the time of the Follow-Up survey implementation-.

Direct beneficiaries of the housing programs were not included in the sample, so, as we are going to argue next, outcome variables only capture the externalities effects of the urban treatment. Statistically significant effects associated with proximity using data from Follow-Up can be interpreted as the casual housing-investment effect of the treatment over the indirectly affected households.

The measure of distance used is *Proximity*. This variable is defined as:

$$Proximity_{in} = -\frac{distance_{in}}{100}$$

Where $distance_{in}$ is calculated as the smallest euclidean distance (in meters) from the residence i to the closest public housing project n.

Table 3.1 displays the background characteristics of the households and their residences, and some metrics of housing quality perception. Since the exogenous variable that we exploit to implement the quasi-experimental approach is the proximity from every household to the housing project, we analyse the variation of the units of observation's characteristics across it. We divide the sample in 2 sub-groups, those who are below the proximity median at neighborhood level, and those who are above. Mean is displayed in Column (1), while differences in mean are reported in Column (2).

[7] As additional data, we count with drone aerial imagery of the neighborhoods intervened for years 2017 and 2018. However, it's not possible to use this data to make statistical inference since i) We count with few observations, and ii) Aerial identification of the residences is very complex and inaccurate. Nevertheless, an exploratory analysis was made to have a better understanding of the observable type of investment that households made. This information can be found in Appendix C.1.

Regarding the Household Characteristics, households head that reside closest to the project have in average -2.30 years less, the probability of being female is 5.42 % larger, and have in average 0.07 more members in the familiar group. No other statistically significant differences in mean are found for these observable characteristics. It is particularly important that there are not significant differences in labor or total household income in Baseline, since income heterogeneity is introduced to the regression models in Chapter 4.

Table 3.1: Baseline Households and Residences Characteristics

	Households furthest from the project	Households closest to project
	Mean	Difference from most distant households
	(1)	(2)
Household head Age	55.07	-2.30**
	[15.58]	(0.89)
Household head is Female (%)	66.47	5.42***
	[47.24]	(1.06)
Household head is Married (%)	40.28	-0.42
	[49.08]	(1.31)
Household head Years of schooling	8.11	-0.06
	[5.25]	(0.11)
Household Size	3.78	0.07*
	[1.91]	(0.04)
Labor Income (CLP)	487297.84	5784.60
	[258083.64]	(9152.45)
Total Income (CLP)	542604.81	1971.57
	[292317.63]	(13191.90)
State of conservation of the house materials	0.76	0.01
	[0.43]	(0.01)
It's proprietary (%)	73.26	1.90
	[44.29]	(1.41)
Own percieved status level	4.72	-0.03
	[1.41]	(0.03)
Own percieved Housing Quality	4.75	-0.00
	[1.61]	(0.07)
Aspired HQ - Current perceived HQ	2.13	-0.03
	[1.89]	(0.05)
Knows about the project	0.49	0.21***
	[0.50]	(0.01)
Dislikes the project	0.14	0.03***
	[0.35]	(0.01)
Observations	850	895

Notes: This table displays the background characteristics of the households and their residences at Baseline survey. Column 1 shows the mean of the households furthest from the housing project. Column 2 displays the difference in means between households closest to project and those farther away. Monetary variables are in chilean pesos (CLP). Exchange rate in 2018: 1 USD = 650 CLP.

Moreover, regarding the Residence Characteristics, no differences in mean are found for the proportion of the homeowners over the total residences, and the quality of construction materials. This last one is registered by the pollster, and therefore, the subjective perception of the members of the household does not affect this metric. These two variables are relevant since it allows us to assume that the externalities effects -that depend on the proximity to the housing project- are not related to the greater probability of owning the dwelling in which they live, or to the relative quality of the infrastructure of the residence.

No statistically significant differences in mean are found for their perceived own socioeconomic Status Level and Housing Quality, nor in the perceived housing quality aspiration gap, calculated as the aspired housing quality level minus the current perceived housing quality. We can infer from this that housing quality aspirations in Baseline are not affecting the housing externalities found.

Finally, a significantly greater fraction of the households that are closest to the project know about the project (70 % vs 49 %), which is very intuitive, since it could be assumed that they have greater probability of receiving all types of information from the housing project just from direct observation and interaction with neighbors. Also, 3 % more households dislike the project when they are closer to it.

Chapter 4

Reduced Form Results

In this section, we propose a linear specification to try to estimate the investment externalities effects and to test the hypothesis that states that housing behaviour is affected by the new public housing projects. Recalling that first order conditions for housing investment are given by Equation 4:

$$h_i^{I*} = \frac{(1-\gamma)}{\phi}\left(\bar{H}_n^d - R_i/r_n\right) + \frac{\gamma}{p_n}(w_i - R_i)$$

With $\overline{H}_n^d \equiv f(h_p, d_{pi})$.

Then, we estimate:

$$Outcome_{i,t=1} = \beta_0 + \beta_1 Proximity_i + \beta_2 Outcome_{i,t=0} + \sum_{j=1}^{N} \gamma_j HousingProject_i + \varepsilon_i \quad (4.1)$$

Which allows us to accept or reject the null hypothesis defined as:

- $H_0 : \beta_2 = 0 \Longrightarrow \bar{H} = 0$. The average household behavior related with housing investment is unaffected with the urban treatment.

- $H_1 : \beta_2 > 0 \Longrightarrow \bar{H} > 0$. The housing investment habits of the households are affected positively in average. This is, public urban investment acts as a complement, and therefore households invest more in housing assets.

- $H_2 : \beta_2 < 0 \Longrightarrow \bar{H} < 0$. The housing investment habits of the households are affected negatively in average. This is, public urban investment acts as a supplement, and therefore households invest less in housing assets.

Models were estimated by Ordinary Least Squares and clustering standard errors at Block-level.

4.1. Housing Investment

To study Housing Investment externalities we first separate these investments by class, since the behavioural economics behind the investment may differ according to the asset category and its purpose. Thus, we will focus in 2 main asset classes:

A. **Housing Quality** assets, which include construction and remodeling of rooms, inner walls, external walls, roof, windows, bathrooms, yard, inner floor and external floor.

B. **Security** assets, including the remodeling and installment of external fences, alarms and barbed wire.

The basis of this separation is that we are assuming that investments in Housing Quality respond to keeping up with the housing quality of the surroundings, and, on the other hand, we suppose that investments in Security are caused by other phenomena, which will be discussed in this chapter. Average amount invested on every sub-class is reported in Table D.1

Outcome variables used for the analysis are first in the extensive margin; i) Did the household invested, and ii) In how many assets did the household invested, and second, in the intensive margin, what is the amount of money that the households invested. We do a breakdown for each asset class. Later on this chapter we will discuss the implications of the model when income heterogeneity is introduced.

4.1.1. Probability of Investing

First, we are going to discuss the results on the investment decision by asset classes. Outcome is a dummy variable that takes the value 1 if the household performed any investment in the last year at the moment of the survey and 0 if not, for every asset class. Regression results are displayed in Table 4.1. Housing Quality effects are presented in Panel A, while Security effects in Panel B.

Statistically significant effects are found for Pooled regressions (Column 1). For every extra 100 meters of Proximity to the housing project, the probability that a household will invest in Housing Quality increases by 0.8 %. This effect is -0.7 % for Security assets. If we separate the analysis by Groups, it's possible to notice that there are relevant differences among them (Column 1 versus Column 2).

In the case of Housing Quality investments, households that were surveyed after the public housing project was inaugurated (Group 1) have an increase in the probability of investing of 1.3 %. No effect was estimated for those who were surveyed before the project was inaugurated (Group 2). Regarding Security investments, almost all the effect is found in Pooled regressions is carried out by Group 1. Households have 0.16 % less probability of investing in Security assets for each 100 mts. of proximity only if the project hadn't been inaugurated yet. This effect is null for Group 2 using a significance level of 0.05. This suggests that there are anticipation effects for Security and no anticipation effects for Housing Quality in terms of probability of investment change.

Table 4.1: Impact of Proximity to Housing Project on the Probability of Investing

	Full Sample	Group 1	Group 2
	(1)	(2)	(3)
Panel A: Remodeled (Housing Quality)			
β_1: Proximity in hundreds of mts.	0.008***	-0.002	0.013***
	(0.003)	(0.003)	(0.004)
Mean (Follow Up)	0.312	0.345	0.298
Outcome in Baseline	X	X	X
Housing Project-Fixed Effects	X	X	X
Observations	1763	530	1233
Panel B: Remodeled (Security)			
β_1: Proximity in hundreds of mts.	-0.007***	-0.016***	-0.003*
	(0.001)	(0.001)	(0.002)
Mean (Follow Up)	0.052	0.053	0.051
Outcome in Baseline	X	X	X
Housing Project Fixed Effects	X	X	X
Observations	1763	530	1233

Notes: This table displays the OLS regression results of proximity to housing projects on the Probability of Investing in housing assets (Equation 4.1). The unit of observation is the household. Standard errors clustered at the neighborhood level are shown in parenthesis. Housing-Projects fixed effects are included in all regressions. Outcome variable in Baseline and a mising value dummy for Baseline observations are included as controls. Panel A reports the effect of Proximity (calculated as $-(DistanceToProject)/(100meters)$) on a variable that indicates whether the household invested in Housing Quality assets (=1) or not (=0) in Follow-Up survey. Housing Quality assets include: construction and remodeling of rooms, inner walls, external walls, roof, windows, bathrooms, yard, inner floor and external floor. Panel B reports the effect of Proximity on a variable that indicates whether the household invested in assets related to Security (Follow-Up). Security assets include the remodeling and installment of external fences, alarms and barbed wire. Column (1) display the results using the whole sample. Column (2) report results for Group 1 -Households living in neighborhoods in which the housing project hadn't been inaugurated at the moment of Baseline survey implementation-. Column (3) report results for Group 2 -Households living in neighborhoods in which the housing project had already been inaugurated at the moment of Baseline survey implementation-. $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

4.1.2. Number of Assets

Then, we want to assess the effects of housing externalities on the number of assets invested, in order to see the efforts on investment diversification. Outcome variable is the number of assets in which investment was performed in the last year for every asset category. Regression results are displayed in Table 4.2. Column (1) includes the whole sample, while (2) and (3) show the results for Groups 1 and 2 respectively. Panel A displays the result for Number of Assets in Housing Quality, while Panel B shows the results for the Number of Assets in Security.

Table 4.2: Impact of Proximity to Housing Project on Number of Assets

	Full Sample	Group 1	Group 2
	(1)	(2)	(3)
Panel A: Number of Assets Invested (Housing Quality)			
β_1: Proximity in hundreds of mts.	0.022***	0.003	0.033***
	(0.007)	(0.006)	(0.009)
Mean (Follow Up)	0.725	0.830	0.680
Outcome in Baseline	X	X	X
Housing Project Fixed Effects	X	X	X
Observations	1763	530	1233
Panel B: Number of Assets Invested (Security)			
β_1: Proximity in hundreds of mts.	-0.010***	-0.019***	-0.005***
	(0.001)	(0.001)	(0.002)
Mean (Follow Up)	0.076	0.057	0.084
Outcome in Baseline	X	X	X
Housing Project Fixed Effects	X	X	X
Observations	1763	530	1233

Notes: This table displays the OLS regression results of proximity to housing projects on the Number of Assets invested (Equation 4.1). The unit of observation is the household. Standard errors clustered at the neighborhood level are shown in parenthesis. Housing-Projects fixed effects are included in all regressions. Outcome variable in Baseline and a mising value dummy for Baseline observations are included as controls. Panel A reports the effect of Proximity (calculated as $-(DistanceToProject)/(100meters)$) on a variable that indicates whether the household invested in Housing Quality assets (=1) or not (=0) in Follow-Up survey. Housing Quality assets include: construction and remodeling of rooms, inner walls, external walls, roof, windows, bathrooms, yard, inner floor and external floor. Panel B reports the effect of Proximity on a variable that indicates whether the household invested in assets related to Security (Follow-Up). Security assets include the remodeling and installment of external fences, alarms and barbed wire. Column (1) display the results using the whole sample. Column (2) report results for Group 1 -Households living in neighborhoods in which the housing project hadn't been inaugurated at the moment of Baseline survey implementation-. Column (3) report results for Group 2 -Households living in neighborhoods in which the housing project had already been inaugurated at the moment of Baseline survey implementation-. $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Results follow the same intuition as Table 4.1. For the Housing Quality models, it's possible to notice that Proximity is statistically significant for Full Sample and Group 2 estimation. For every 100 mts. of proximity there is an extra 0.033 investment on assets for Group 2 and null effect for Group 1.

On the other hand, regarding the Security assets, Proximity is statistically significant for Pooled , Group 1 and Group 2 estimation. Households in Group 1 invest in 0.019 less assets for every 100 meters of proximity. This effect is -0.005 for Group 2. The interpretation for this result is that households that are farther away from the project invest more in security than those who are closest, but only when the project has already been inaugurated. This suggests that the effect is present for all the implementation timeline, so anticipation effects are present since they occur even before that the social housing project is inaugurated. However, effects in Group 1 are almost 4 times the effects for Group. meaning that anticipation are, again, predominant for Security assets.

4.1.3. Amount Invested

Finally, we want to evaluate the effects of the Proximity to the housing projects on the amount of cash invested in every category. The outcome variable is the amount in thousands Chilean pesos (CLP[8]) invested in every asset class[9].

Regression results are displayed in Table 4.3. For the Amount invested on Housing Quality, positive and statistically significant effects associated with distance were found for Pooled and Group 2 regressions (Columns 1 and 3). On average, for every 100 meters of proximity, households invest 3,906 CLP more. This effect is carried out all by Group 2 -households residing in neighborhoods in which the public housing projects were already inaugurated-, where for every 100 mts. of proximity, an extra 5,847 CLP in investment is performed.

Concerning the Amount invested on Security, negative and significant effects using a 0.05 level of significance were found for Full Sample and Group 1. For Pooled (Group 1) regression, for every 100 meters of proximity, households invest 1,428 (2,894) CLP less.

[8] Exchange rate in July 2018 ≡ 1 USD = 650 CLP.

[9] Top 0.1 % values of the outcome variable for every asset class have been replaced for the value of the percentile 99.5 % in order to diminish the effect of the outliers on the regression estimates. Same procedure was applied for the outcome variable in Baseline survey included as control in Specification 4.1.

Table 4.3: Impact of Proximity to Housing Project on Amount Invested

	Full Sample	Group 1	Group 2
	(1)	(2)	(3)
Panel A: Housing Quality			
β_1: Proximity in hundreds of mts.	3.906***	0.211	5.847***
	(0.808)	(0.968)	(1.251)
Mean (Follow Up)	131.882	135.270	130.436
Outcome in Baseline	X	X	X
Housing Project Fixed Effects	X	X	X
Observations	1755	525	1230
Panel B: Security			
β_1: Proximity in hundreds of mts.	-1.428***	-2.894***	-0.706*
	(0.299)	(0.229)	(0.357)
Mean (Follow Up)	21.002	24.810	19.377
Outcome in Baseline	X	X	X
Housing Project Fixed Effects	X	X	X
Observations	1755	525	1230

Notes: This table displays the OLS regression results of proximity to housing projects on the Amount Invested in housing assets (Equation 4.1). The unit of observation is the household. Standard errors clustered at the neighborhood level are shown in parenthesis. Housing-Projects fixed effects are included in all regressions. Outcome variable in Baseline and a mising value dummy for Baseline observations are included as controls. Panel A reports the effect of Proximity (calculated as $-(DistanceToProject)/(100meters)$) on a variable that indicates whether the household invested in Housing Quality assets (=1) or not (=0) in Follow-Up survey. Housing Quality assets include: construction and remodeling of rooms, inner walls, external walls, roof, windows, bathrooms, yard, inner floor and external floor. Panel B reports the effect of Proximity on a variable that indicates whether the household invested in assets related to Security (Follow-Up). Security assets include the remodeling and installment of external fences, alarms and barbed wire. Column (1) display the results using the whole sample. Column (2) report results for Group 1 -Households living in neighborhoods in which the housing project hadn't been inaugurated at the moment of Baseline survey implementation-. Column (3) report results for Group 2 -Households living in neighborhoods in which the housing project had already been inaugurated at the moment of Baseline survey implementation-. Exchange rate in July 2018 ≡ 1 USD = 650 CLP. $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

4.2. Income Heterogeneity

After estimating the average externalities effects at neighborhood level, we want to identify who are the households that are investing the most and being mostly affected by these externalities effects. Therefore, in this section we repeat the analysis reported in Tables 4.1, 4.2 and 4.3 by introducing heterogeneity between households income per capita.

Outcome variables are, for every asset class; the decision of investing or not, the number of assets in which investment was performed, and the amount of the investment in CLP. For every outcome variable, we estimate the following specification:

$$\begin{aligned} Outcome_{i,t=1} = \beta_0 + \beta_1 Proximity_i + \beta_2 Top\ Income_{i,t=0} + \beta_3 Proximity_i \times Top\ Income_{i,t=0} \\ + \theta Outcome_{i,t=0} + \gamma HousingProject + \varepsilon_i \end{aligned} \tag{4.2}$$

Where $Top\ Income_{i,t=0}$ is a dummy variable that takes the value 1 if the total income per capita of the household i is above certain threshold and 0 if below[10]. Income cut-off utilized are pertaining to the Top 50 % and 90 % of Income within every neighborhood. This variable considers labor and all other sources of income such as governmental subsidies and aids.

Importantly, we know that household income is orthogonal to distance, and therefore to Proximity, from the results displayed in Balance Table 3.1. On average, when the baseline survey was taken, Labor Income was 487,297 CLP, while Total Income, that includes labor income, subsidies and other income sources, was 542,604 CLP. No statistically significant difference in means is reported for neither of these variables across the distance cut-off, which corresponds to the median value of the variable that measures the distance to the housing project.

Regression results are displayed in Table 4.4. Panels A.I and A.II display the regression results using the total income value of the percentile 50 and 90 as thresholds for the income dummy variable for Housing Quality. Panels B.I and B.II are analogous to panels A.I and A.II but for Security assets. Columns 1 to 3 display the results for the Probability of Investing, columns 4 to 6 report the results for Number of Assets and columns 7 to 9 display results for the Amount Invested. As the previous Tables, we separate the analysis by groups. Columns 1, 4 and 7 use Full Sample, while columns 2, 5 & 8 and 3, 6 & 9 for Groups 1 and 2, respectively.

[10] Additional covariates in the regression follow the same idea as Specification 4.1. $Outcome_{i,t=0}$ is a control of the value of the outcome variable in Baseline survey. Outliers in this variable are replaced with a 0 and included in the regression with the dummy $NA_{t=0}$.

Table 4.4: Impact of Proximity to Housing Project on Outcome Variables, Heterogeneity by Income

	Probability of Investing			Number of Assets			Amount (CLP)		
	Full Sample	Group 1	Group 2	Full Sample	Group 1	Group 2	Full Sample	Group 1	Group 2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A.I: Housing Quality - Top 50 % Income									
β_1: Proximity (100m)	0.004	-0.001	0.007	0.011*	-0.016*	0.028***	-0.012	-10.093***	6.103***
	(0.00458)	(0.00457)	(0.00618)	(0.00689)	(0.00864)	(0.00891)	(1.10118)	(0.97195)	(1.75427)
β_3: Top 50 % Income per capita	0.045***	0.026	0.057**	0.080***	0.048	0.084**	58.579***	64.102***	49.182***
	(0.01675)	(0.01723)	(0.02175)	(0.02736)	(0.03193)	(0.04041)	(9.71546)	(10.03302)	(12.39027)
β_2: Proximity × Top 50 % Income per capita	0.008	0.000	0.013*	0.021***	0.036***	0.010	8.154***	21.751***	-0.771
	(0.00590)	(0.00492)	(0.00722)	(0.00803)	(0.00780)	(0.01286)	(1.44326)	(1.57310)	(2.26172)
Mean (Follow-Up)	0.313	0.346	0.299	0.541	0.588	0.521	130.312	133.620	128.887
Outcome in Baseline	X	X	X	X	X	X	X	X	X
Housing Project Fixed Effects	X	X	X	X	X	X	X	X	X
Observations	1748	529	1219	1748	529	1219	1741	524	1217
Panel A.II: Housing Quality - Top 10 % Income									
β_1: Proximity (100m)	0.006**	-0.004	0.011***	0.022***	0.001	0.035***	1.283	-3.663***	4.110***
	(0.003)	(0.003)	(0.004)	(0.005)	(0.006)	(0.007)	(0.831)	(0.978)	(1.293)
β_3: Top 10 % Income per capita	0.052*	0.148***	0.007	0.022	0.107	-0.026	76.504***	141.084***	47.101***
	(0.027)	(0.036)	(0.031)	(0.055)	(0.096)	(0.082)	(7.601)	(20.875)	(7.550)
β_2: Proximity × Top 10 % Income per capita	0.017***	0.027***	0.013	-0.005	0.019*	-0.019	21.008***	40.122***	11.974***
	(0.006)	(0.005)	(0.008)	(0.026)	(0.011)	(0.039)	(1.644)	(2.956)	(2.118)
Mean (Follow-Up)	0.313	0.346	0.299	0.541	0.588	0.521	130.312	133.620	128.887
Outcome in Baseline	X	X	X	X	X	X	X	X	X
Housing Project Fixed Effects	X	X	X	X	X	X	X	X	X
Observations	1748	529	1219	1748	529	1219	1741	524	1217
Panel B.I: Security - Top 50 % Income									
β_1: Proximity (100m)	-0.009***	-0.014***	-0.008***	-0.011***	-0.015***	-0.011***	-0.440***	-0.658**	-0.725***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.003)	(0.139)	(0.254)	(0.128)
β_3: Top 50 % Income per capita	0.012**	0.006	0.021***	0.011	0.011	0.019**	-5.811***	-4.821***	-3.320*
	(0.006)	(0.008)	(0.007)	(0.009)	(0.010)	(0.010)	(1.171)	(1.038)	(1.720)
β_2: Proximity × Top 50 % Income per capita	0.004**	-0.004***	0.010***	0.003	-0.007***	0.011**	-1.806***	-4.386***	0.292
	(0.002)	(0.001)	(0.003)	(0.003)	(0.002)	(0.004)	(0.360)	(0.232)	(0.536)
Mean (Follow-Up)	0.051	0.053	0.051	0.059	0.060	0.059	7.469	9.709	6.504
Outcome in Baseline	X	X	X	X	X	X	X	X	X
Housing Project Fixed Effects	X	X	X	X	X	X	X	X	X
Observations	1748	529	1219	1748	529	1219	1741	524	1217
Panel B.II: Security - Top 10 % Income									
β_1: Proximity (100m)	-0.007***	-0.013***	-0.004**	-0.010***	-0.016***	-0.006***	-0.323*	-0.523***	-0.451
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.192)	(0.161)	(0.356)
β_3: Top 10 % Income per capita	0.024***	-0.067**	0.062***	0.022***	-0.068**	0.058***	-15.639***	-48.632***	-1.741***
	(0.007)	(0.030)	(0.011)	(0.008)	(0.030)	(0.009)	(1.834)	(0.821)	(0.615)
β_2: Proximity × Top 10 % Income per capita	-0.002	-0.027***	0.009***	-0.001	-0.025***	0.008***	-7.803***	-22.619***	-0.913***
	(0.002)	(0.004)	(0.002)	(0.003)	(0.005)	(0.002)	(0.846)	(0.174)	(0.265)
Mean (Follow-Up)	0.051	0.053	0.051	0.059	0.060	0.059	7.469	9.709	6.504
Outcome in Baseline	X	X	X	X	X	X	X	X	X
Housing Project Fixed Effects	X	X	X	X	X	X	X	X	X
Observations	1748	529	1219	1748	529	1219	1741	524	1217

Notes: This table displays the OLS regression results of proximity to housing projects on the Probability of Investing, Number of Assets, and Amount Invested in housing assets (Equation 4.2). The unit of observation is the household. Standard errors clustered at the neighborhood level are shown in parenthesis. Housing-Projects fixed effects are included in all regressions. Outcome variable in Baseline and a mising value dummy for Baseline observations are included as controls. Panels A.I and A.II display the regression results using the total income value of the percentile 50 and 90 as thresholds for the income dummy variable for Housing Quality. Panel B.I and B.II display the regression results using the total income value of the percentile 50 and 90 as thresholds for the income dummy variable for Security assets. Columns 1 and 3 display the results for the Probability of Investing, columns 4 to 6 report the results for Number of Assets and columns 7 to 9 display results for the Amount Invested. As the previous Tables, we separate the analysis by groups. Columns 1, 4 and 7 use Full Sample, while columns 2, 5 8 and 3, 6 9 for Groups 1 and 2, respectively. Group 1 are the households living in neighborhoods in which the housing project hadn't been inaugurated at the moment of Baseline survey implementation. Group 2 are the households living in neighborhoods in which the housing project had already been inaugurated at the moment of Baseline survey implementation-. Exchange rate in July 2018 ≡ 1 USD = 650 CLP. $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Probability of Investing

The model provides various insights. First, regarding the Probability of Investing, we can notice that pertaining or not to the top 50 % of income does not affect the decision of investing in Housing Quality with Proximity for any of the samples, using a significance level of 0.05. However, when the threshold is put in the 90 % percentile of income, statistically significant effects are found in Pooled, Group 1 and Group 2 regressions. In Pooled regression, for every 100 mts. of proximity, the probability of investing increases in 0.6 %, and an extra 1.7 % for the richest households. For Group 1, the interaction term takes all the statistical significance, meaning that all the investment is being performed by the 10 % richest households, increasing the probability of invest a 2.7 % for each 100 mts. of proximity. Income does not afect the Probability of Investing for Group 2.

Concerning the decision of investment in Security assets, statistically significant and heterogeneous effects are encountered for the interaction between Proximity and Top Income variables for all samples. Using percentile 50 as threshold for Security assets, we find that the probability of investing is reduced with Proximity in 0.9 %, 1.4 % and 0.8 % for Full Sample, Group 1 and Group 2 respectively. However, for Pooled and Group 2 regressions, we found an increase in the probability for families with higher income as Proximity increases (an extra 0.4 % and 1.0 %, each). This effect is is still negative for Group 1 (-0.4 %). This finding is relevant since the direction of the effect seems to depend on the relative income of the household.

For percentile 90 of Income, effects remain consistent with findings using percentile 50. Effects of Proximity for Full, Group 1 and Group 2 are -0.7 %, -1.3 % and -0.4 %. For the interaction term, no statistically significant effects are found for Pooled Sample, since effects from Group 1 and Group 2 cancel each other out (-2.7 % and 0.9 %, respectively).

Number of Assets

Regarding the Number of Assets, for Housing Quality, using a significance level of 0.05, we have that being above the median in Income only has statistically significant effects associated with Proximity for Group 2; adding an extra 0.028 number of assets for every 100 meters. However, the interaction term has statistically significant and positive effects for both Full Sample and Group 1 (0.021 and 0.036 extra assets, respectively). Interestingly, moving the threshold to percentile 90 of income imply having no effects associated with Income.

Security assets on the other hand, have heterogeneous effects depending on Sample. For Top 50 % Households, negative and statistically significant effects are found for Proximity term, nevertheless, as it was reported for the Probability of Investing, we have negative effects for the interaction term using Group 1 (-0.007 extra assets) but positive effects for Group 2 (0.011 extra assets per 100 mts.). Same intuition follows for Top 90 % Income, with effects associated to the interaction term of -0.025 and 0.008 for Groups 1 and 2.

Amount Invested

Finally, the most economically relevant effects are found in the Amount Invested. For Housing Quality assets, it's possible notice that there are positive significant effects for the interaction term using Full Sample and Group 1. For Full sample, richest 50 % of households capture average all the effect; for every 100 mts of proximity, top 50 % households invest almost 8,154 CLP extra for Full Sample. Heterogeneous effects are found for Group 1. Proximity effects are negative (-10,093 CLP per 100m), and positive for the interaction term (21,751 CLP per 100m). Null effects are found for the interaction term using Group 2.

Using the percentile 90 threshold, we got that a significant part of the investment is carried out by top 10 % income households, investing on average an extra 21,008 CLP for each 100 mts of proximity (40,122 CLP and 11,974 for Groups 1 and 2, respectively). However, we still find statistically significant effects for Proximity, -3,663 and 4,110 CLP for Groups 1 and 2-.

Regarding Security assets, despite of the fact that we found heterogeneous effects for the Probability of Investing and Number of Assets, we find only negative statistically significant or null effects for both 50 and 90 percentile thresholds.

Using the Top 50 % Income interaction, we got that for Pooled Regression, Proximity's effect is -440 CLP and -1,806 for the interaction term. These effects are -658 CLP and -4,386 CLP for Group 1 and -725 CLP and no effect, for Group 2. Regarding the results for Top 10 % Income households, statistically significant effects related to the interaction term are found for all the 3 samples; Full, Group 1 and Group 2 samples (-7,803, -22,619 and -913 CLP for every 100m, respectively). Weak to statistically null effects are present for Proximity, which indicates that almost all the effect is captured by the richest households; Proximity's effect for Group 1 is -523 CLP, and null for the other samples.

The biggest unknown in this problem is about the effects for Group 2. While we had significant and positive effects for Probability of Investing and Number of Assets, null effects are found for the 50 percentile and negative effects for the 90 percentile. However, the last one is not a large effect. Since less than 6 % is actually investing in Security assets (Follow-Up), this change of the direction of the effect across the outcome variables may be caused by some outliers.

4.3. Discussion

Results among the homogeneous models are very consistent across all the 3 outcome variables exploited. Regarding Housing Quality, households are more likely to invest (in probability and number of assets) and allocate more money in their investments the closer they are to the housing project. However, this effect is identified only on the neighborhoods in which the housing project had already been inaugurated, and with some probability, there was not only a pure housing quality gap mechanism explaining the effect on investment, but also a social one, since interaction between the public housing program and the former neighbors can't be discarded.

Group 2 households, on average and for every 100 meters of proximity, have a 1.3 % greater chance to invest in Housing Quality, they invest in 0.033 more assets, and finally, they invest an extra 5,847 CLP. Recalling the theoretical model, this implies that we can interpret that housing externalities effects in terms of Housing Quality act as a complement; public investment comes with more investment carried out by the adjacent households.

On the other hand, investment related to Security assets are mainly reflected on anticipation effects. These are, on average, statistically significant, negative, and are more modest than Housing Quality investments. Group 1 households, on average and for every 100 meters of proximity, have 1.6 % less probability to invest in Security, they invest in 0.019 less assets, and finally, they invest an extra -2,894 CLP. Recalling the theoretical model, this implies that we can interpret that housing externalities effects in terms of Security act as a complement; public investment comes with less investment carried out by the adjacent households.

Regarding Security investments, two qualitative theories that could fit the results obtained in Tables 4.1, 4.2 and 4.3 are that; *a*) People with less contact with incoming neighbors from vulnerable contexts have more negative prejudices about them that neighbors that have more contact with them, which drives them to invest in security, or *b*) Housing projects subsidize Security assets by the construction and remodeling of lights, sidewalks, streets, traffic signals, among others. However, alternative *a*), which has social integration implications, is not likely to be predominant since from Table 3.1, we know that, first, on average 70 % of the households that are closer to the housing project have a greater probability of knowing the project, in contrast to the 50 % of the households that are furthest from project at Baseline level, and second, only 17 % of the households that are closest to the project dislike the project (this percentage is 14 % for households above the distance median from each project).

Several insights arise when income heterogeneity is included in the model. First, despite than previously we had obtained no anticipation effects for Housing Quality, we find heterogeneous effects for Number of Assets and Amount Invested. Richest households tend to invest more for each 100 meters of proximity even before the housing project hasn't been inaugurated yet. However, this effect is negative for households with less resources, which could imply that the housing quality gap surpasses certain threshold that discourages them to invest as response to not being treated, as its described in Undurraga, 2017 [10] (however, we know that they still invest with Proximity once the housing project is inaugurated, but only compensating 6/10 of the anticipation effects, on average). The effect over the 50 % richest households in Amount Invested absolute value is 2 times the effect over the rest, and almost 11 times for 10 % richest households.

On the other hand, for Security assets, heterogeneous effects are now present after the project was inaugurated (Group 2) in Probability of Investing and Number of Assets outcome variables. Even-though we found negative effects associated with distance in homogeneous models, introducing household total income to the model indicates that Top Income households do invest more in Probability and Number of Assets as Proximity increases. However, null and negative effects (-913 CLP for every 100 mts.) are still found in the amount invested for top 50 % and 10 %, respectively. This last result is not intuitive, and can be explained by outliers, since average Security investment in Follow-Up is very low (6,504 CLP for Group 2) in comparison to Housing Quality investment (128,887 CLP for Group 2).

4.4. Back-of-the-envelope calculation for Housing Investment Externalities

In order to calculate the impact of the social housing program, in terms of housing investment externalities, we use the coefficients estimated in Table 4.3 and we implement it having as example the housing project built in the west frontier of La Pintana, named *Celestín Freinet*. La Pintana is a low income commune with 13.86 % of its population below the poverty line[11]. Near 177,000 inhabitants reside in this zone.

Celestin Freinet construction was approved in 2016 and consisted on 392 duplex-type apartments with sizes between 55.48 m^2 and 55.85 m^2 each built in 4-story buildings, 4 one-story buildings for social headquarters (equipment) with a total constructed area of 264.60 m^2 and some covered pedestrian circulation. It also included 219 parking spaces. Total project investment was 10,005 million CLP [12].

Since we estimated the effects in housing investment before and after the housing projects were inaugurated, we can estimate the total externalities effects after the intervention.

Using:

- $HousesInRing_i$ as the number of houses in the area formed by ring between i and $i+1$ hundreds of meters from the housing project.
- $\beta^{g=2}$, the coefficient estimated in table 4.3 for Proximity $\left(\frac{-distance(m)}{100}\right)$ for group 2, after the housing project was inaugurated.

We compare the effect on the 9 inner rings to the outer ring. Thus, we calculate within the 900 meters of analysis the following equation:

$$\text{EXT} = \sum_{i=1}^{N=10} HousesInRing_i \times \beta^{g=2} \tag{4.3}$$

In order to estimate the number of houses for each ring i, we count the number of houses in the ring 1 (orange ring in Figure 4.1), corresponding to a total of 306 houses in an surface of 75,500 m^2.

Then we estimate the number of houses for each remaining ring as:

$$HousesInRing_i = \frac{HousesInRing_1}{Area(Ring_1)} \times Area(Ring_i)$$

[11] Compared to 6.2 % of income poverty of whole RM. Source: CASEN survey 2015 [11].
[12] Source: Environmental Assessment Service (SEIA) [12]. Using a CLP/USD exchange rate of 667

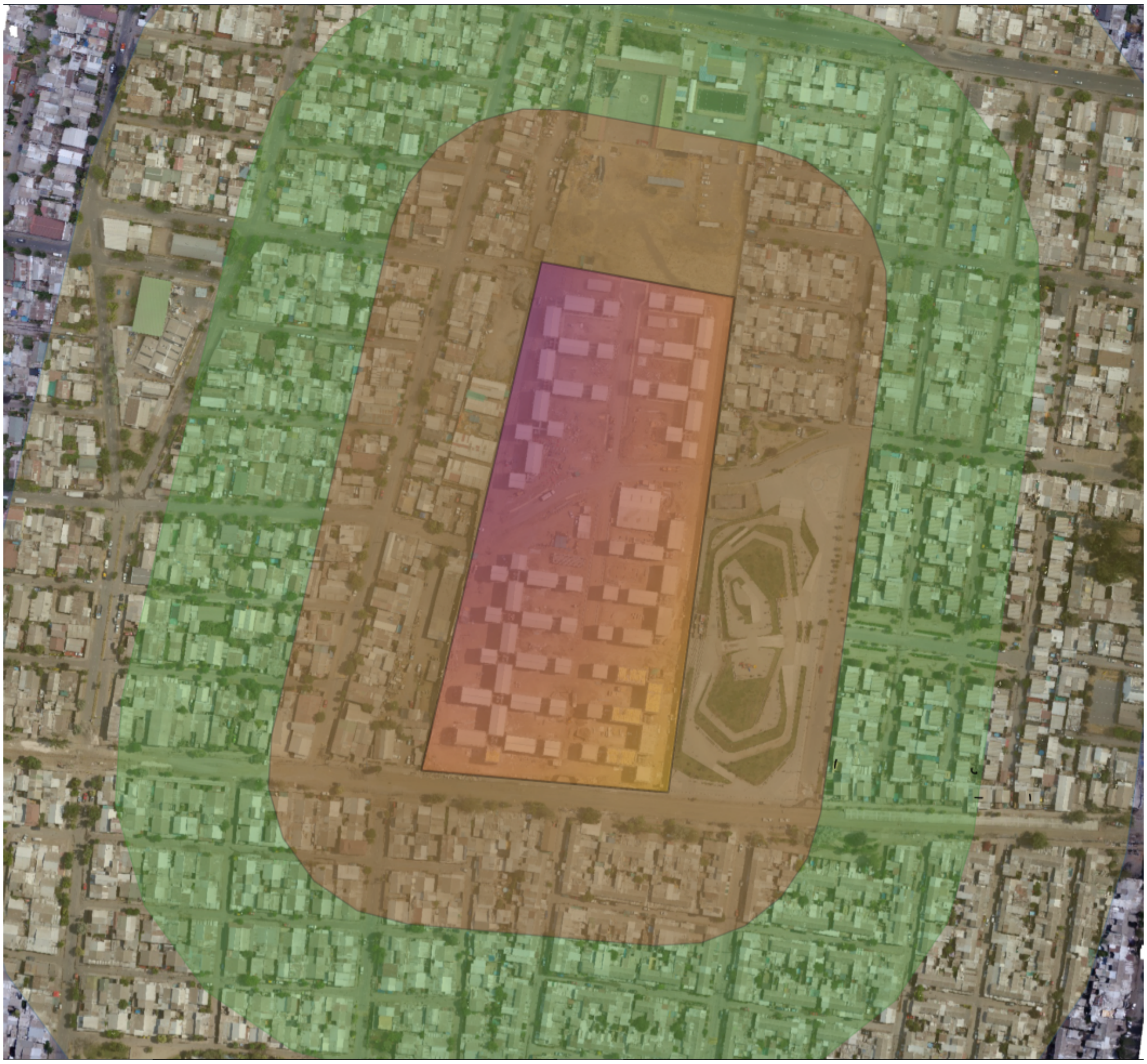

Figure 4.1: Rings of 100 meters around Celestín Freinet housing project (2018).

After computing equation 4.3, we get that housing investment externalities are up to 511 million CLP. This implies that extra social return on investment from the housing project is 5.11 %[13]. While this is a small amount compared to the investment, it only accounts for investment externalities to Housing Quality, so housing projects should have an extra benefit to consider in cost-efficiency analysis.

[13] $ROI = (\frac{511M}{10{,}005M} \cdot 100)\,\%$

Chapter 5

Conclusions

Housing interventions have impact not only in welfare of the directly affected beneficiaries, but also in the decisions and wellness of the former inhabitants of the neighborhoods. We show that some of these housing externalities effects depend of the distance of the former households to the urban intervention using a quasi-experimental approach by exploiting the implementation of a social housing program in RM, Chile.

FSV-DS49 public housing program not only has a superior housing quality than the average residence in the intervened neighborhoods, but also improve the public spaces and build amenities that enhance social integration. We propose a general equilibrium theoretical model that indicates that households want to fill the housing quality gap created by the housing projects by investing more.

To test the theoretical model we use a reduced form estimation. We evaluate the probability of investing, the number of assets, and the amount invested. We show that former households decisions could be affected depending on the asset type. First, regarding their investment on Housing Quality, we found positive effects; on average, households that live closer to the housing projects have a higher probability to invest, tend to invest in more assets and more money that those who live furthest away, but only when the housing project has already been inaugurated. This implies that, on average, housing investment externalities act as a complement for Housing Quality.

On second place, in regard to investment on Security, negative anticipation effects are found on average. We argue that housing externalities act as a supplement in this case. Households that live closer to the project tend to invest more, in probability, types of assets and in cash, than those who are closest. This effect is predominant when housing projects have not been inaugurated yet. We cannot confirm the theory that the prejudices and negative beliefs that uninformed -and therefore farther away households- have about the incoming neighbors, drives them to invest more in security, since data shows that households that are closer to the project are the ones that have a greater probability to dislike the project. Results favor the hypothesis that this phenomena is due to a subsidy of Security assets coming from the social housing projects.

When income heterogeneity is introduced to the model, additional insights on the externalities effect of the housing program are obtained. For Housing Quality, heterogeneous anticipation effects are now found. Despite of the evidence that indicates that income hasn't a major impact with proximity once the housing project has already been inaugurated, richest households tend to invest more with proximity before the housing project hasn't been inaugurated yet. However, this effect is negative for households with less resources, so they could be discouraged to invest. Despite that most vulnerable households still increase their investment with proximity to the housing project, it only compensates 6/10 of the anticipation effects on average.

On the other hand, income heterogeneity on Security assets regression results indicate that heterogeneous effects are now present after the project was inaugurated. Eventhough we found negative effects associated with distance in homogeneous models, introducing household total income to the model indicates that top income households do invest more in probability of investing and the number of assets in which the household invested as proximity increases. However, we don't find any heterogeneous effect on the amount invested.

Eventhough that the estimated externalities effects are modest, our study provides statistically significant evidence that households invest more when housing investment is performed nearby. This would work as a first evidence of how the households want to bridge the gap when their perceived housing quality of their surroundings is altered when also social integration plays a part, as described in the theoretical model presented in Chapter 2.

The results obtained by reduced form estimation follow the intuition of the theoretical model, but structural estimation of the parameters of the model is required in order to identify the transmission mechanisms of the externalities effects of the urban intervention. As we illustrated by simulating the externalities effects, these are not correctly identified if decay rate of the spillovers are not linear, as the theoretical model predicts.

Finally, a back-of-the-envelope calculation using the results obtained, allows us to estimate the order of magnitude of these externalities effects relative to the government investment. Investment in housing quality of the surrounding households could account an extra 5.1 % return on investment. This indicates that housing projects are much more cost-effective if the goal of the public policy is to increase the overall housing quality of the neighborhood and all of its direct consequences. However, the positive externalities effects are mainly capitalized by the richest households of every neighborhood, while households with less economic resources suffer negative externalities on average.

Future work involves to incorporate an objective measure of housing investment. In addition, an important issue about using surveys is that retrieving a bigger sample could not be possible because of budget constraints. Using aerial images could solve both of these problems. Yue Huang et. al. (Working Paper) [13] approach uses high-resolution satellite imagery and deep learning methods as input of empirical models to calculate and evaluate the impact of treatment in anti-poverty programs. In addition, using the same approach, Gechter & Tsivanidis (Working Paper) [14] find reduced form evidence of sizable spatial spillovers that impact surrounding locations from an urban renewal.

In this regard, an evident bias emerges from our approach; self-reported investments could be different from the ones captured by analyzing the imagery. In our descriptive analysis from aerial images, 24 % of Households are identified as they made significant investments in their houses. On the other hand, 31.3 % of the households report to have invested in the quality of their houses in the last year (at Follow-Up survey). Despite that these proportions are not very different from each other, households could over-report their own investments and, on the other hand, we may not be able to capture the non-observable investment from aerial imagery.

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Annexes

Annexed A. Theoretical Model Demonstrations

A.1. Demonstration 1: Optimal consumption and housing investment in one period model

Following the definition in Section 2.2, if the housing externalities act as a complement to housing consumption, the problem that households face is:

$$\max_{c,h^I,h^R} \; c_i^{1-\gamma}(h_{in}^R + \phi h_i^I - \overline{H}_n^d)^\gamma \tag{A.1}$$

subject to:

$$c_i + r_n h_{in}^R + p_n h_i^I \leq w_i \tag{A.2}$$

$$r_n h_i^R = R_{in} \tag{A.3}$$

Since restriction A.3 is active, we can reformulate the household problem as it follows:

$$\max_{c,h^I} \; c_i^{1-\gamma}(R_{in}/r_n + \phi h_i^I - \overline{H}_n^d)^\gamma \tag{A.4}$$

subject to:

$$c_i + R_{in} + p_n h_i^I \leq w_i \tag{A.5}$$

Problem Lagrangian is:

$$\mathcal{L} = c_i^{1-\gamma}(R_{in}/r_n + \phi h_i^I - \overline{H}_n^d)^\gamma - \lambda(c_i + R_{in} + p_n h_i^I - w_i)$$

$$\frac{\partial \mathcal{L}}{\partial c_i} = 0 \Rightarrow \lambda = (1-\gamma)\left(\frac{(R_{in}/r_n + \phi h_i^I - \overline{H}_n^d)}{c_i}\right)^\gamma \tag{A.6}$$

$$\frac{\partial \mathcal{L}}{\partial h_i^I} = 0 \Rightarrow \lambda = \frac{\gamma\phi}{p_n}\left(\frac{(R_{in}/r_n + \phi h_i^I - \overline{H}_n^d)}{c_i}\right)^{\gamma-1} \tag{A.7}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = 0 \Rightarrow c_i = (w_i - h_i^I p_n + R_{in}) \tag{A.8}$$

(A.6) = (A.7)

$$\left(\frac{(R_{in}/r_n + \phi h_i^I - \overline{H}_n^d)}{c_i}\right) = \frac{\gamma\phi}{(1-\gamma)p_n}$$

$$\Longleftrightarrow c_i = \left(\frac{(R_{in}/r_n + \phi h_i^I - \overline{H}_n^d)}{c_i}\right)\frac{(1-\gamma)p_n}{\gamma\phi} \tag{A.9}$$

(A.8) = (A.9)

$$(w_i - h_i^I p_n + R_{in}) = \left(\frac{(R_{in}/r_n + \phi h_i^I - \overline{H}_n^d)}{c_i}\right)\frac{(1-\gamma)p_n}{\gamma\phi}$$

Rearranging:

$$\boxed{h_i^{I*} = \frac{(1-\gamma)}{\phi}(\bar{H}_n^d - R_{in}/r_n) + \frac{\gamma}{p_n}(w_i - R_i)} \tag{A.10}$$

Replacing (A.10) in (A.9):

$$c_i^* = (1-\gamma)(w_i - R_{in} - \frac{\phi}{p_n}(\bar{H}_n^d - R_i/r_n)) \tag{A.11}$$

A.2. Demonstration 2: Housing Externalities in 2 periods model

We have that when the housing project hasn't been approved yet, by definition, $\bar{H}_n^d = 0$.

From Equation (A.10):

$$\begin{aligned}
\Delta h_i &= h_{i,t=1}^{I*} - h_{i,t=0}^{I*} \\
&= \frac{(1-\gamma)}{\phi}(\bar{H}_n^d - R_{in}/r_n) + \frac{\gamma}{p_n}(w_i - R_i) - \frac{(1-\gamma)}{\phi}(-R_{in}/r_n) + \frac{\gamma}{p_n}(w_i - R_i) \\
&= \frac{(1-\gamma)}{\phi}(\bar{H}_n^d - R_{in}/r_n) - \frac{(1-\gamma)}{\phi}(-R_{in}/r_n) \\
&= \frac{(1-\gamma)}{\phi}\bar{H}_n^d
\end{aligned} \tag{A.12}$$

Annexed B. Theoretical Model Simulation

In order to check that the basic model produces plausible results, we implement a Montecarlo simulation and compare the output using the first order conditions from the optimization problems of the basic and with-externalities models. The parameters and variables used are reported in Table B.1. For most variables, we use the information provided in the estimation made by the Central Bank of Chile (2016) [7]. Monetary units are expressed in thousands of Chilean pesos (CLP).

Table B.1: Parameters and mean variables used for simulation

	Value	Description	Source
Parameter			
γ_1	0.21	$\frac{\text{Average housing rental price}}{\text{Average household income}}$	Central Bank of Chile (2016)[1]
γ_2	0.31	$\frac{\text{Average total housing consumption}}{\text{Average household income}}$	Own Estimation
p	450	Average price of housing investment ($\$M$)	Own Estimation
h_p	6000	Public housing investment size (m^2)	Own Estimation
ϕ	10	Marginal housing utility of investment	Arbitrary, to be estimated
υ	0.1	Marginal effect of public housing investment	Arbitrary, to be estimated
θ	1	Degree of decay of externalities	Arbitrary, to be estimated
Variable			
$\bar{h}$	44	Average house size in Puente Alto (m2)	CChC (2020)[2]
$\bar{w}$	529	Average household income in RM ($\$M$)	Central Bank of Chile (2016)
$\bar{R}$	260	Average housing rental price ($\$M$)	Central Bank of Chile (2016)

[1] Chilean Central Bank (2016) [7]
[2] Chilean Chamber of Construction (2020) [15]

In the simulations, for every variable x we generate random variables using a normal distribution truncated at 0, with mean $\bar{x}$ and standard deviation $\bar{x} \cdot 15\,\%$. We generate 10.000 observations for each variable. Furthermore, for every observation, we generate a random distance to the housing project drawn from an uniform distribution $d \sim U(0, 1000)$ in meters.

B.1. Basic model simulation

First, from generated variables, we calculate the vector of rental prices per m^2:

$$r = \frac{R}{\bar{h}}$$

Where the main assumption in this data generating process is that R and h (a constant) are not correlated with each other. In some sense, this assumption allows us to represent the non-tradable nature of the houses since the prices are not -only- given by the size of the house, but also for its individual, non-observable, characteristics. Even though this may seem like an irrelevant assumption, it will allow us to easily introduce variation on every term of FOC and easily estimate some of the parameters in the next section.

Recalling that the first order condition for housing consumption is:

$$h_{in}^{*} = \gamma_1 w_i / r_n$$

Evaluating the random variables in FOC, we obtain the vector of optimal rented housing size h^*, whose distribution is displayed in Figure B.1. Average optimal $\bar{h^*_{in}}$ is 49 m^2, which is very close to the mean average housing size in Puente Alto Commune, used as reference to generate the variables. We will re-define the output in this stage of the simulation as $\hat{h^R} \equiv h^*$ and use it in the model extension with externalities as an 'exogenous' result in order to solve the utility maximization problem for less endogenous variables; goods consumption c_i and housing investment h^I_{in}[14].

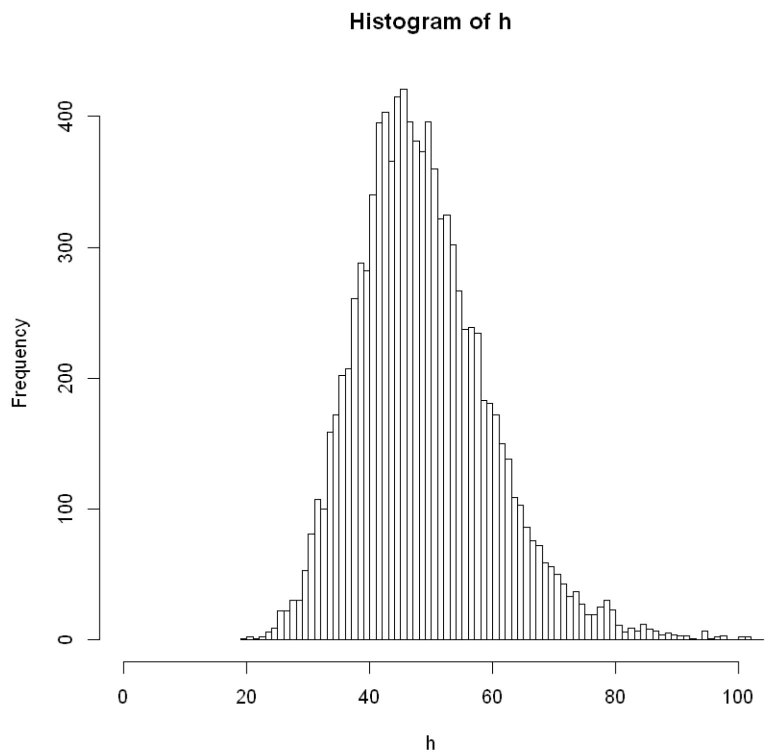

Figure B.1: Simulation of optimal housing rental consumption h_{in} in Basic Model.

B.2. Model-with-externalities simulation

Recalling the theoretical model in Section 2.2, this extension adds two important features to the basic model. First, households not only decide the size of the house that they will rent -h^R_{in}-, but also the housing investment performed in it, h^I_n. Second, the investment made by the insertion of a housing project in the neighborhood changes the perception of quality of the former neighbors, and therefore produces externalities effects that impact over the optimal decisions of housing investment.

From the Basic model simulation, we obtain that the optimal housing rental consumption is given by the vector $\hat{h^R_n}$. We would like to impose that this will be the optimal decision in this model as well -with or without externalities effects-, since we are only trying to address,

[14] The assumption here is that Basic model, which is used by Central Bank of Chile to calculate the housing price index as an input to model the optimal monetary policy to control inflation, delivers plausible estimates for housing consumption.

from what was not housing rental expenses (goods consumption), which part corresponds to housing investment expenses. As explained previously, the constraint $\hat{h_n^R} r_n = R_n$ captures the idea that there are frictions that make it difficult for the households to vary the housing rental consumption (adding 1 extra m^2 in the house by renting it) or to move from one house to another.

Since γ_1 is calculated only taking account of the housing rental expenses, we have to find another parameter that incorporates the expenses related to housing investment in the Cobb-Douglas utility function. Following the idea of Central Bank of Chile (2016), we define γ_2 as:

$$\gamma_2 \equiv \frac{\text{Average total housing consumption}}{\text{Average household income}}$$

We obtain the average total housing consumption by adding to the mean housing rental price $\bar{R}$, generated in the previous section, the amount of money that households would assign to housing investment. This information is obtained from a Baseline survey, which was implemented prior to the housing intervention[15]. The surveys were performed to random -indirectly affected- households before and after the social housing project construction.

In order to incorporate externalities, we assess in the simulation the size of public housing investment, its effects and the parameters associated[16]. Recalling that the first order condition for housing investment is:

$$h_i^{I*} = \frac{(1-\gamma_2)}{\phi}\left(\frac{\upsilon h_{pn}}{d_{pi}^{\theta}} - \hat{h_{in}^R}\right) + \frac{\gamma_2}{p_n}(w_i - R_{in})$$

We perform the simulation for the two different cases, with and without housing intervention in the neighborhood ($h_{pn} = 0 \wedge h_{pn} \neq 0$). Replacing in FOC the arbitrary set parameters ϕ, θ and υ, the calculated parameters h_{pn}, γ_2 and p_n, the simulated optimal housing rental consumption $\hat{h_{in}^R}$ and simulated variables w_i, R_{in}, we obtain the simulation of the optimal housing investment h_i^{I*} for every situation, whose distribution is displayed in Figure B.2. As it's possible to notice, the housing intervention makes the optimal housing intervention distribution to shift to the right.

[15] The question was formulated as follows: '*Home improvements.* In this section I am going to ask you about possible remodeling or repairs that you have made to your house during the last 12 months [...]. 1) Have you remodeled your house in the last 12 months? (Yes/No), 2) Approximately, how much money did you spend to make this upgrade? (Open)'. Questions were asked separately for room expansion, room division/joining, painting, roof, windows and bathrooms repair, planting plants in gardens, floor repair and installation of security systems.

[16] The size chosen to produce this parameter is 6000 m^2, which is approximately the surface of the social housing project built in Celestín Freinet, which is a representative project of DS-49. The covered area by the building was measured from aerial drone imagery.

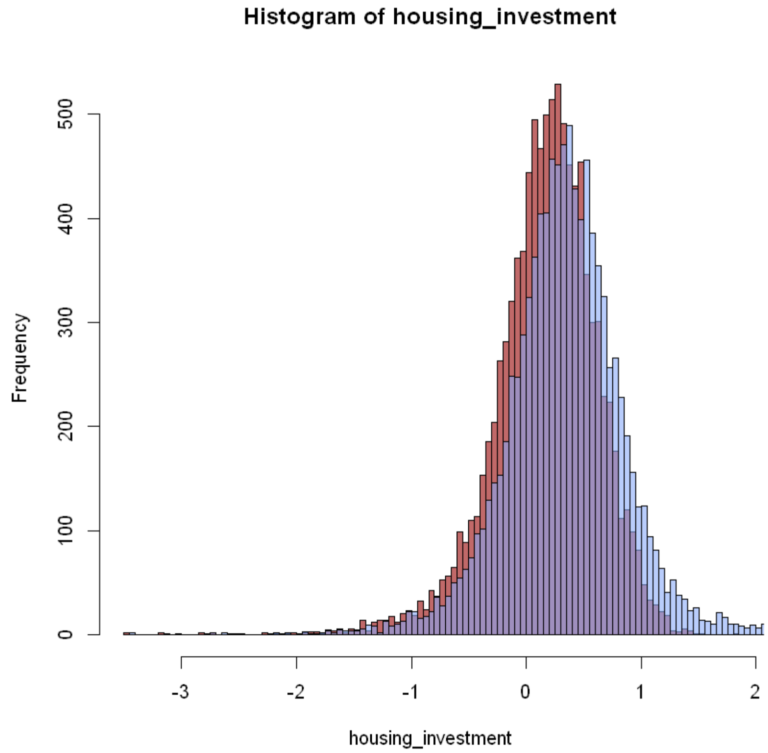

Figure B.2: Distribution of optimal housing investment without intervention (in red) and optimal housing investment with intervention (in blue).

Given the arbitrary parameters used, mean housing investment with and without intervention are 0.45 and 0.17, respectively. Values less than 0 mean that there is housing disinvestment, which is consistent respect to the descriptive analysis of data in Section **??**, that shows that empirically there are houses that show a detriment in the general appreciation of housing quality.

Even-though the mechanisms of propagation of the effects of the intervention are clearly identifiable in the simulated model -since we know the data generating process-, we are interested on a simple way to estimate how this externalities effects affect the houses as a function of distance.

B.2.1. Estimating housing investment as a function of distance

Setting h_1 and h_0 as the vectors of optimal housing investment decisions with and without the intervention, we compute OLS estimates for h_1 as a linear function of h_0 and the closest distance (in hundreds of meters) from the house to the social housing project d^{100}. Formally we estimate:

$$h_1 = \beta_0 + \beta_1 \cdot h_0 + \beta_2 \cdot d^{100} + \varepsilon \tag{B.1}$$

The results for the estimates are displayed in Table B.2. We obtain that the estimated coefficient for the distance d^{100} is significant and negative as expected.

Table B.2: Regression Estimation Results

	Housing Investment in $t = 1$
Distance (hundred of meters)	-0.12^{***}
	(0.00)
Housing Investment in t = 0	1.02^{***}
	(0.03)
Intercept	0.90^{***}
	(0.03)
R^2	0.17
Adj. R^2	0.17
Observations	10,000

Notes: This table implements the model: $HousingInvestment_{t=0} = \beta_0 + \beta_1 Distance + \beta_2 HousingInvestment_{t=0} + \varepsilon_i$. Housing investment in time $t = 0$ is without intervention and Distance corresponds to the euclidean distance from house i to the closest housing project in hundreds of meters. Values in parenthesis are to sample standard deviation of the estimates of the variables. $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Even though we are specifying that distance affects linearly, when in fact we know from the data generating process that distance affects exponentially to the housing investment, the variable d^{100} -of distance in meters- produces a correct linear fit when compared to in-differences dependent variable, as is possible note from Figure B.3. In the graph, externalities effects are calculated as $\Delta = h_1 - h_0$.

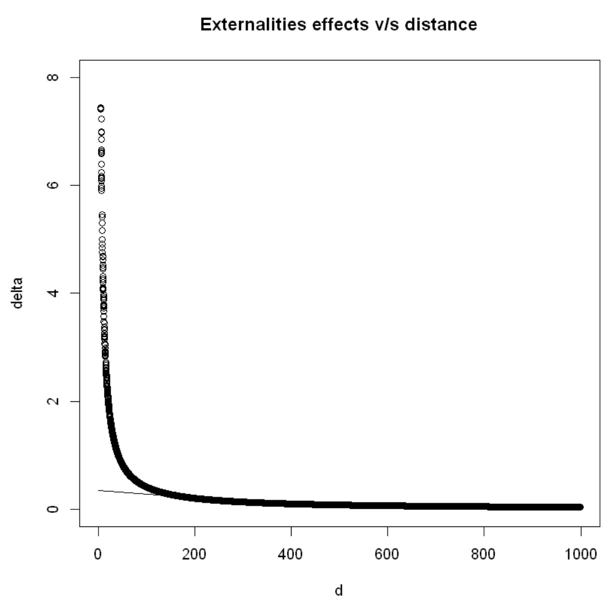

Figure B.3: Housing externalities v/s distance

Results shown explain that the farther away the households are, the less additional investment is optimally chosen by the households. This is because the externalities effects attenuate with distance. Nevertheless, overall fit of the model is low, with a R^2 of 0.17. This can be explained because we are fitting a non-linear effect with a linear model.

Annexed C. Data

C.1. Exploratory analysis of housing quality

Housing investment could be materialized in many ways; extensions, renewals, repairs and quality upgrades, and they depend of the households and houses characteristics. In order to describe what is the predominant form of housing investment, and the overall quality of the houses in the sample, we develop a simple descriptive analysis of housing quality and housing investment by manually classifying and comparing houses of the sample in baseline and follow up.

From the total universe of households surveyed in Baseline and Follow Up (1719), we searched their location coordinates using Google Maps Geocoding API, obtaining 1250 unique and correctly identified addresses. From those 1250, surveys whom neighborhoods have imagery for Baseline and Follow Up were selected, letting 984 observations left. We select the closest house from the location coordinates from each observation and year, finishing with 899 observations for every year, due to missing parts of images, distortions, among others.

Figure C.1: Merged image of a house in 2017 (left) and 2018 (right).

Finally, houses images for every year in the remaining sample were merged to a single image, were the final picture contained the image of the house in 2017 and in 2018, as is shown in figure C.1, and then were classified respect to 3 attributes: housing quality in 2017 (*HQ2017*), measured as the proportion of the roof that was in good shape; housing quality in 2018 (*HQ2018*); and housing extension (*EXT*), that represents the percentage of the house extended from 2017 to 2018. Summary statistics for the final classification, along with the distance (in meters) from houses to the social housing project are presented in Table C.1.

From this exploratory analysis we have three main insights. First, as shown in Figure C.2.1, only a small percentage of households invest, either in renewals, repairs and upgrades (RRU) or in extensions. We expect that the externalities effects on housing investment to be small. This implies that to detect the effect as a function of distance we need a larger number of observations. Second, even though the correlation between RRU and extension is

0.4, it is possible to notice from Figure C.2 that, from those who invest, they do it mostly either on renewals or extension, but rarely both. This means that the number of cases that an extension improves the proportion of roof of good quality is low (18). Third, from Figures C.2.2 and C.2.3, we know that investment in extensions are larger and mostly positive in percentage -taking 2017 as base year-, in comparison with (dis)investments in RRU, that are smaller and not always positive.

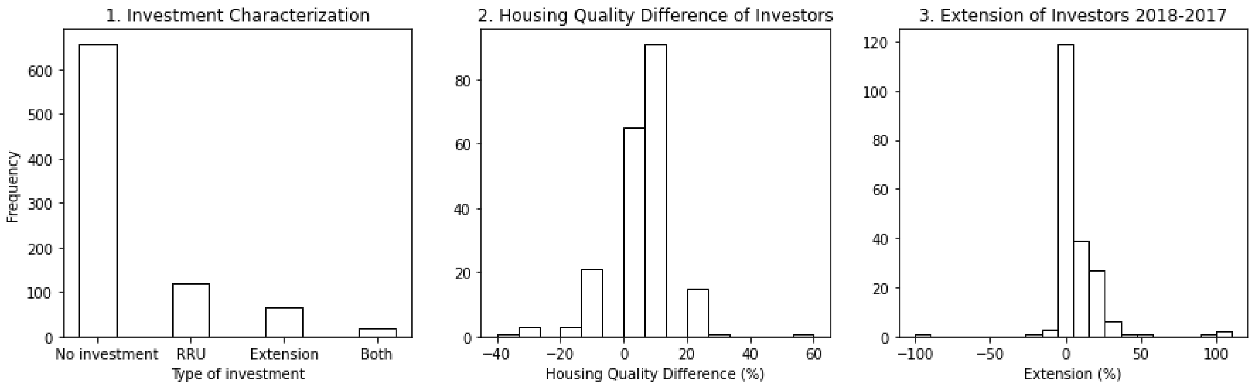

Figure C.2: Housing investment characterization

Probably, the sample of 859 images presented in this section are not sufficient to provide a significant evidence about housing quality investment as a function of the distance to exposure of the treatment, which corresponds to the implementation of the social housing project. Since the manual classification is considerably time consuming and also is based on a subjective, prone-to-human-error classification, we implement an automatic deep learning algorithm to infer housing quality in all the houses that are captured in the neighborhoods aerial imagery. In this regard, 2 different strategies need to be implemented in order to correctly identify the forms of investment presented. First, the detection of roof renewals, repairs and upgrades, and second, the detection of house extensions.

Table C.1: Summary statistics for housing quality - manual classification.

	HQ2017	HQ2018	EXT	distance
N	859	859	859	859
Mean	0.843	0.855	0.019	246
Std	0.103	0.098	0.133	183
Min	0	0.4	-1	0
25 %	0.8	0.8	0	89
50 %	0.8	0.9	0	203
75 %	0.9	0.9	0	380
Max	1	1	3	1012

C.2. Questionnaire Example

Módulo 14: Mejoras a la Vivienda En esta sección le voy a preguntar por posibles remodelaciones o arreglos que usted le haya hecho a su vivienda durante los últimos 12 meses. Para cada una de las remodelaciones le haré varias preguntas.							
	14.1 ¿Ha realizado [REMODELACIÓN] a su vivienda durante los últimos 12 meses? 1. Sí → ***Pase a 14.4*** 2. No 99. NS-NR	**14.2 ¿Por qué no la ha realizado?** 1.Falta de dinero 2.Falta de tiempo 3.No tiene los materiales 4.No conoce a nadie que lo haga 5.No sabe hacerlo 6.No le interesa 7.No lo necesita 8. Ya lo hice. 9. NS-NR	**14.3 ¿Aspira a realizar esta mejora en un futuro cercano?** 1. Sí 2. No 99. NS-NR **→ En ambos casos pase a siguiente mejora**	**14.4 Aprox. ¿cuánto dinero gastó en hacer esta mejora?** (En caso de ser vía subsidio, indique el monto del subsidio recibido) 99. NS-NR	**14.5 Aprox., ¿cuántas horas diarias destinó a hacer esta mejora?** 88. No lo hicimos nosotros 99. NS-NR	**14.6 ¿Cuánto esfuerzo económico significó esta mejora?** 1. Mucho esfuerzo 2. Esfuerzo moderado 3. Poco esfuerzo 4. Ningún esfuerzo 99. NS-NR	**14.7 ¿Cree usted que podría haber invertido más en hacer esta mejora?** 1. Sí 2. No 99. NS-NR **→ Pase a siguiente mejora**
1. Construcción/ampliación de piezas							
2. División/unión de piezas							
3. Pintado/rep. murallas internas							
4. Pintado/rep murallas externas							
5. Pintado/reparación rejas externas							
6. Reparación del techo							
7. Reparación de ventanas							
8. Reparación de baños							
9. Poner flores o plantas en el patio exterior							
10. Reparación piso interno							
11. Reparación piso externo							
12. Instalación de nuevas rejas o candados en puertas y ventan.							
13. Instalación de algún sistema de alarmas							
14. Instalación de púas, cerca eléctrico o elementos cortantes sobre rejas, muros o panderetas							
15. Otras reparaciones							

Figure C.3: Questionnaire Example: Module 14 contains questions about housing improvements, including housing investment.

C.3. Retrieving a measurement of distance

This study wants to obtain the impact of the housing intervention depending on the proximity of the houses to the housing projects. Therefore, a correct measurement of distance is imperative in order to get unbiased estimators of the externalities effects.

The original survey's database contained mainly 2 measurements where the distance from the houses to the project could be retrieved of. In first place, we count with a measurement of distance between the epicenter of the block where the house was placed and the housing project -called 'Block distance'-. This measurement has a low probability to be incorrectly computed, but it is highly imprecise; for instance, houses that are placed 200 meters among each other could have the same measurement of distance if they are in the same block. In second place, we count with the coordinates of the house in WGS84 projection. These coordinates were obtained from a gadget held by the pollsters, but digitization was not automatic. Manual typing caused that more than 90 % of the observations were in an incorrect format that not corresponded precisely to WGS84 coordinates.

To get a measurement of distance that was both precise and correctly computed, we implemented a series of actions to validate the final distance variable, and established a hierarchy criteria to select the most correct measurement available.

1. From the addresses of each household, we implement an algorithm to retrieve the coordinates by using the Google Maps API 'Geocoding´. Geocoding receives the address of each house and gives back a single duple containing the latitude and longitude coordinates in EPSG:3857 projection, so re-projection was required in order to compare and calculate the distances. Due to the precise identification of the coordinates of Geocoding API trough addresses, the distance obtained by this measure has top priority in the confidence level hierarchy. Over 90 % of the coordinates could be obtained this way.

2. We implement an algorithm that corrects the format problems of the WGS84 coordinates digitized by the survey takers. Even-though we can recover a great percentage of the variable observations by this method, there is more dispersion than expected about the distribution of these coordinates in the neighborhoods. We assume that this can be caused by human error -the survey takers made mistakes while writing the data provided by the gadget-, or machine error -the GPS gadget was providing imprecise approximations of the location of the survey taker-.

3. Aerial identification of housing projects allows us to precisely calculate the distances from the coordinates obtained (from both Geocoding and Processed survey) to the housing projects. An algorithm calculates the closest distance from the houses to all of the projects, resulting in 2 new measures of distance: Geocoding distance (d^G) and Processed survey distance (d^S) in addition to the original Block-to-project distance (d^B). As it was mentioned before, even-though the rate of obtainment of the distances is quite high, there are still missing observations for some criteria, and, most importantly, there is variance between the different measurements of distance for the same household. Then, the hierarchic criteria to select the final distance, given that the measurement is precise, was given by:
$$d^G > d^S > d^B$$

Due to the possibility of obtaining incorrect distance measurements from the different sources, we implemented a cross-validation method to ensure that the calculations are correct. The method consists in checking if the distance with highest hierarchic priority (d^G) can be validated by the other distance measurements by calculating the difference between them. If the difference is in a tolerance interval determined by an arbitrary threshold and the compared distance, then we assume that this measurement is correct.

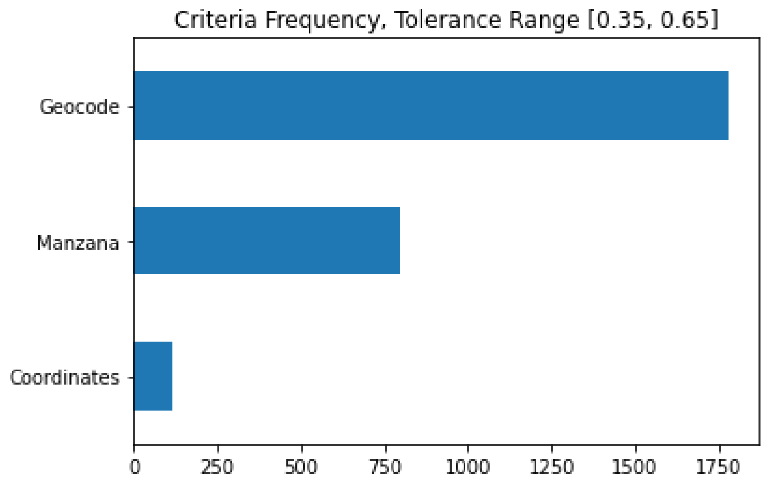

Figure C.4: Distance Variable Selection Frequency

The constructed interval for every different observation consists in the distance of comparison $\pm 15\,\%$. If the distance is out of the interval, then we apply the same test with the distance from the Processed Survey. If it doesn't work either, then the selected distance from that observation is the one measured by the Block-to-project distance, which is the most reliable one, but the less precise.

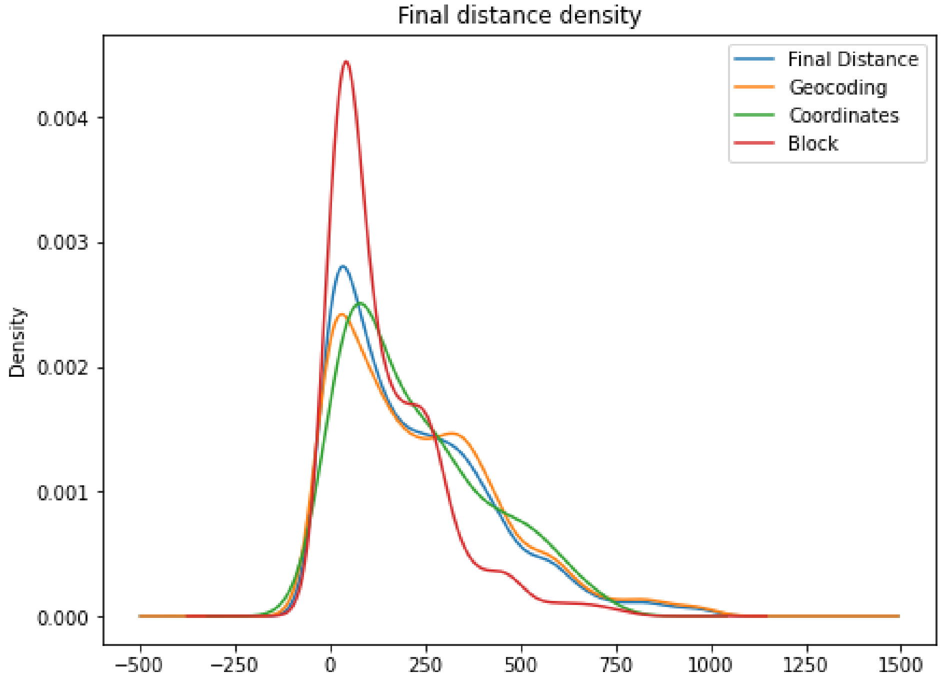

Figure C.5: Final Distance Density Function

Great part of the observations selected could be retrieved from the most precise method -d^G-, as it's possible to notice from Figure C.4. Most importantly, distances obtained from every method have a similar distribution Figure C.5. This implies that results should not be biased by the selected method of the distance measurement.

Annexed D. Results

D.1. Amount invested by asset sub-class

Table D.1: Amount invested by asset sub-class

	Baseline	Follow-Up
	Mean [SD]	Mean [SD]
	(1)	(2)
Housing Quality Assets		
Room Construction	135611	70203
	[706725]	[511004]
Room Remodeling	10656	2957
	[124914]	[49904]
Internal Wall Remodeling	22422	38813
	[141312]	[176591]
External Wall Remodeling	14714	2281
	[210260]	[20782]
Roof Remodeling	30707	20178
	[245531]	[183438]
Window Remodeling	5295	4590
	[54712]	[101781]
Bathroom Remodeling	23501	11932
	[146958]	[120382]
Garden Remodeling	3231	1235
	[64172]	[25966]
Internal Floor Remodeling	22392	56646
	[143905]	[265741]
External Floor Remodeling	13415	7195
	[114081]	[59740]
Security Assets		
External Fence Installation	11714	6416
	[126115]	[59215]
External Fence Remodeling	7158	4735
	[71592]	[53759]
Alarm Installation	169	164
	[5215]	[4052]
Barbed Wire Installation	1098	1695
	[23298]	[68512]

Notes: This table displays the amount invested by households en every asset sub-class. Average amounts are reported at Baseline and Follow-Up survey. Column 1 shows the average amount invested in Baseline. Column 2 displays the mean at Follow-Up. Variables are in chilean pesos (CLP). Exchange rate in 2017: 1 USD = 650 CLP.