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Autores

Héctor Posada

Andrés García

David Londoño

COLOMBIA CIENTÍFICA Conocimiento Global para el Desarrollo

ALIANZA EFI Economía Formal e Inclusiva

The external effects of public housing developments on informal housing: The case of Medellín, Colombia

Héctor M. Posada [*] Andres García-Suaza [†] David Londoño [‡]

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Abstract

Provision of new subsidized housing projects has proven to be an effective alternative to reduce the high level of quantitative housing deficit in developing countries. However less is known about how these housing projects affect the quality of the surrounding habitat, especially when projects are located in areas with high levels of precarious housing. Using highly granular public information from Medellin, Colombia, we estimate the causal effect of new social housing projects (VIS) on housing quality indicators in the neighborhood. To estimate this causal effect, we use the geological quality of the land as an instrumental variable for a measure of exposition to new social housing projects. Our results show that new VIS projects lead to a reduction of informal housing, poverty, and crime in the neighborhood.

JEL Classification: R23, R31, R58

Keywords: Public housing, Informal housing, Neighborhoods, Developing country

[*]Universidad de Antioquia. Email: hector.posada@udea.edu.co.

[†]School of Economics, Universidad del Rosario. Email: andres.garcia@urosario.edu.co.

[‡]Universidad de Antioquia. Email: david.londonoa@udea.edu.co.

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1 Introduction

One in three households in Colombian and Latin-American cities lives in a precarious dwelling regarding tenure security, construction materials durability, access to public services, or interior space availability (Daude, 2017). Faced with this situation, the governments of the region at the national and local levels have sought to promote different policies to mitigate the housing deficit. In Colombia, an important share of the resources for housing provision and habitat improvement programs is channeled through the development of real estate projects known as Social Interest Housing (VIS, for its Spanish acronym) or Priority Interest Housing (VIP, for its Spanish acronym) programs. Beneficiary households can access new homes with subsidized prices and subsidized interest rates. An example of this type of policy is the Mi Casa Ya housing program (see Minvivienda, 2015). Since 2015, Mi Casa Ya has allowed 162,000 households to purchase their own homes. Recent evidence reveals that this program has generated significant reductions in poverty and improvements in the employment indicators of directly benefited households (Lopez, 2021).

The impacts of public housing projects can go beyond the changes they generate on directly benefited households. They are also real estate development policies that can significantly affect their surrounding habitat. Public housing in Colombia are often on the peripheries, due to space restrictions and high land prices in the center of cities. These projects are often close to the extensive informal urban settlements typical of the region[1]. In these locations, projects can stimulate the growth of settlements and precarious housing by inducing higher levels of migration of low-income households seeking to take advantage of improved urban infrastructure. At the same time, the quality of the VIS housing projects may not represent an improvement over current habitability conditions. In that case, the projects will replicate the same social problems of the settlements, further depressing the area where they are located.

The projects could also generate positive externalities in the territory. For example, they could build trust in the private sector and incentivize housing construction by private developers through a demonstration effect (see Schwartz et al., 2006, for a detailed discussion). These projects can also bring about better suitability of the land for construction, expand public infrastructure and improve roads. This would reduce connection costs to the public utilities network, improving the quality of the habitat in the neighborhood. Thus, the potential ambiguous effect of public housing projects on the quality of housing in their areas of influence is highlighted.

Empirically verifying these opposite effects is important from an academic point of view. There is relatively abundant evidence for the North American case, of the positive impacts of social housing projects in the territory. Consistently it has been shown that programs such as the Low Income Housing Tax Credit (LIHTC) and the provision of public housing in New York led to a renovation processes in their areas of influence

[1]One of the most characteristic features of Latin-American cities and, in general, of cities in developing countries, is the existence of informal settlements where low-income households live in housing with some type of precariousness, in peripheral areas disconnected from the opportunities offered by the city. According to the 2017 RED report (see Daude, 2017), approximately 1 in 5 urban households lives in an informal settlement.

(see Ellen et al., 2001; Schwartz et al., 2006; Baum-Snow and Marion, 2009), increasing economic activity, reducing poverty and crime rates (see Freeman, 2003; Freedman and Owens, 2011; Diamond and McQuade, 2019; González-Pampillón, 2022). However, little is known about the impacts of social housing projects in the territory when these projects are built in areas that exhibit large housing deficits, informal urban settlements, and a high potential for rural-urban migration. From a public policy point of view, it is important to judge the effectiveness of housing provision more precisely, specially considering that this policy competes with other alternatives widely used in the region, such as in-situ habitat improvements, (like the Mejoramiento Integral de Barrios Program in Colombia DNP, 2009), and considering that in the North American case, it has been showed that alternatives like rental subsidies are superior to other options in terms of efficiency (see Olsen et al., 2005, for a discussion of alternative policy instruments).

Using highly granular public information from Medellin, Colombia, in this paper, we estimate the causal effect of new social housing projects (VIS) on housing quality indicators of the neighborhood in locations characterized by high levels of informal housing. To quantify the causal effect of the policy in the neighborhood, we regress indicators of housing precariousness against a measure of exposition to new public housing projects, and a rich set of economic and geographical controls. We also use the geological quality of the land as an instrumental variable for our measure of exposition to new housing projects. Our results suggest that a greater indirect exposure of the neighborhood to new public housing projects leads to a significant drop in housing precariousness. Specifically, a 10% increase in exposure to VIS projects reduces precariousness by 4%. These results are robust to different treatment measures, instrument definitions and geographic units of analysis. We also observed that new VIS projects reduce poverty and crime and increase land values in the neighborhood. These results reveal that VIS projects are not only important for their direct effects on reducing the quantitative housing deficit but also for indirectly help to reduce the qualitative housing deficit in their areas of influence.

We organized the rest of the paper as follows. Section 2 summarizes the literature that studies the indirect impacts of the provision of subsidized housing. Section 3 describes the housing sector and the socioeconomic conditions of Medellín. Section 4 describes the data, the construction of the indicators and the empirical strategy, including the definition of the instrumental variable. Section 5 shows the descriptive statistics. Section 6 presents the main findings and Section 7 the robustness exercises. Finally, Section 8 presents the main conclusions.

2 Related literature

Our study contributes to the growing literature on the effects of public housing projects in developing countries. Previous studies have focused on analyzing the effects of this policy on the directly benefited households. Franklin (2020) reveals how the national public housing program in South Africa generated improvements in the employment indicators of women. In this work, the distance between the city centers and the projects is used to control for the effects of location. Then the results can be interpreted as the effects for households of moving from a precarious housing to a formal housing. However, Picarelli

(2019) shows for this same program that new projects were located in disconnected areas of the cities, which generated worse results in terms of the labor market in the beneficiary households. Summing up, for households, the benefits of moving to a housing of a higher quality were overridden because of the locations of the new projects.

For the cases of Rosario, in Argentina, and São José do Rio Preto and Rio de Janeiro in Brazil, Alzúa (2016) and Chagas and Rocha (2019) indicate, based on experimental evidence, that households benefiting from public housing projects exhibit worse outcomes because the projects were far from the main urban employment centers. In Colombia, the work of Camacho-González (2022) studies the causal effects of the Free Housing Program (PVG, for its Spanish acronym), exploiting the fact that approximately 38% of the beneficiaries were selected through a lottery. The exercise shows that the beneficiary households exhibit better employment indicators. According to the authors,this is because of the greater proximity of the new homes to the opportunities offered by the cities. Similar results were found for the VIS housing program by Lopez (2021). In summary, the evidence shows that, for public housing projects to generate positive effects on household employment indicators, these projects must offer good construction quality and a location close to the opportunities provided by the city.

In contrast, little is known about the effects of these types of projects on neighborhoods. For the case of Montevideo, Uruguay, González-Pampillón (2022) shows that stimulus to housing supply in middle-class neighborhoods generate price increases in surrounding areas. To the best of our knowledge, the only study that analyzes the effects of new housing projects on areas with a high incidence of informal housing is Gechter and Tsivanidis (2020). Using a differences-in-differences strategy, this study shows that the construction of new buildings in downtown areas of the city of Mumbai leads to the reduction of informal settlements and informal employment in the surrounding areas. The authors used unexpected regulatory changes that allowed certain areas to be redeveloped as a source of exogenous variation, and built their settlement measurements trough satellite images and machine learning algorithms.

Our study provides additional features that help to elucidate the external effects of new public housing projects in developing countries. First, we use census data to calculate the incidence of informal housing which allows to provides accurate measures with a high level of granularity. Second, we use geo-located information from the universe of new public housing projects in the city of Medellín which combine with the use of census data allows to obtain high statistical power. Finally, our instrumental variables identification strategy takes advantage of the geological quality of the land as a source of exogenous variation of the treatment variable, conditional on a rich number of socioeconomic and urban indicators.

There is abundant evidence of the spillover effects of public housing projects in developed countries, especially in the US. Ellen et al. (2001) indicate how new public housing projects in New York positively affect housing prices in surrounding areas using geo-coded data on real estate transactions between 1980 and 1999 and a difference-in-differences identification strategy. Schwartz et al. (2006) also show for New York that public housing generates external effects on prices and quantifies the magnitude of the impact as a function of the distance to the place of intervention. These authors mention the mechanisms behind the studied causal relationship which are related with the physical infrastructure that makes neighborhoods more or less attractive, with market factors related to an investment that attracts these projects, and with the population dynamics that can increase economic activity or generate congestion. The evidence reveals that, even when positive effects on land prices have been observed, it is also possible to observe negative effects.

The evidence for developed countries also shows that interventions of a larger scale have bigger effects on prices (Ellen et al., 2001; Santiago et al., 2001; Ellen et al., 2007) and additionally have a cumulative effect (Voith et al., 2022). The effects of new housing projects on prices may differ depending on the timing and the context in which they are analyzed. For example, Santiago et al. (2001) show that the effects of subsidized housing in Denver on property prices disappear over time, and become negative when Afro-descendant neighborhoods are considered. In contrast, Funderburg and MacDonald (2010) show that the LIHTC development programs for new housing projects in Iowa have effects that persist in the medium term (5 years or more), while Voith et al. (2022) shows that the effects persist 10 years after the intervention. Asquith et al. (2021) and Daminger (2021) report negative effects on rental value, accompanied by increased immigration in low-income neighborhoods, while Diamond and McQuade (2019) document heterogeneous effects as a function of neighborhood income conditions, finding negative impacts on property values in high-income neighborhoods.

The literature for developed countries also studies the effects of public housing on poverty, household income, and crime incidence, showing mixed results (see Varady, 1982; Agnew, 2010, for an extensive discussion). The seminal study by Freeman (2003) shows that in the United States, subsidized housing programs did not generate a concentration of poverty, while the studies by Olsen et al. (2005), Susin (2005) and Saraswat (2021) reveal that housing projects led to increases in income and improvements in working conditions. In contrast, Baum-Snow and Marion (2009) find that LIHTC developments in Chicago decrease income, because the program led to the influx of low-income households.

Finally, it has also been reported that new housing projects lead to increases in human capital accumulation (Kumar, 2019), improvements in mental health status, and access to health services (Matte and Jacobs, 2000; Fertig and Reingold, 2007; Bailey, 2020; Ding et al., 2022), and reductions in crime rates (Freedman and Owens, 2011; Diamond and McQuade, 2019; Alonso et al., 2019; González-Pampillón, 2022).The literature also has verified a crowding-out effect in housing supply (Sinai and Waldfogel, 2005; Baum-Snow and Marion, 2009; Eriksen and Rosenthal, 2010).

3 Socioeconomic context and the social interest housing policy in Colombia

During the second half of the 20th century, Colombia experienced rapid urban growth because of industrialization and the economic boom in raw materials, which together, prompted the migration of low-income families from rural areas to cities. This accelerated growth implied enormous challenges to providing housing in cities characterized by lagging infrastructure and low institutional capacity. As a result, in 2020 about 5.1 million households (equivalent to 20.8% of total households), experienced some type of housing deficit (Departamento Nacional de Planeación, 2021; DANE, 2021).

In response to these circumstances, different policies have been deployed in Colombia, including providing new subsidized housing or social interest housing (VIS, for its Spanish acronym). A VIS is a housing unit that meets the minimum quality requirements in urban, architectural, and construction design, whose value does not exceed 135 Colombian Minimum Legal Wages (SMLMV, for its Spanish acronym). Currently, the program finances up to 80% of the property value, subsidizes up to 30 SMLMV of the initial fee, and up to 4 pp of the interest rate for seven years. The design of the policy also stipulates that the government will make direct payments to land developers. Subsidies are delivered through financial institutions which classify households according to eligibility criteria and risk definition (Minvivienda, 2015). The subsidies are provided to households with incomes below 4 SMLMV, who do not have their own home and who made a formal request for the benefit. In 2021, the VIS programs benefited nearly 62 thousand households at the national level.

As in the rest of Colombia, Medellín[2] experienced rapid population growth that generated the proliferation of informal settlements that concentrated households with the most significant housing deprivations. According to the 2020 Quality of Life report produced by Medellín Cómo Vamos[3] (Medellín Cómo Vamos, 2020), in 2019 the city had 800,723 households where 17.9% of them faced a condition of qualitative housing deficit. The city also exhibited an unemployment rate of 11.9% in 2018, which was higher than the national average rate (9.7%), and poverty and extreme poverty rates of 14.2% and 3.6%, respectively.

The informal urban growth and the high poverty rates in Medellín can be seen in form of stark spatial inequalities. As shown in Figure 1a, precarious or informal housing is mainly located on the slopes of the periphery to the east and west zones of the city, where the highest rates of multidimensional poverty are found (see Figure 1b). These areas, are also characterized by steep slopes (see Figure 2a), narrow and unplanned streets, and an important lag in the provision of infrastructure, which together have generated a low level of accessibility to job opportunities (see Figure 2b) and other types of opportunities[4].

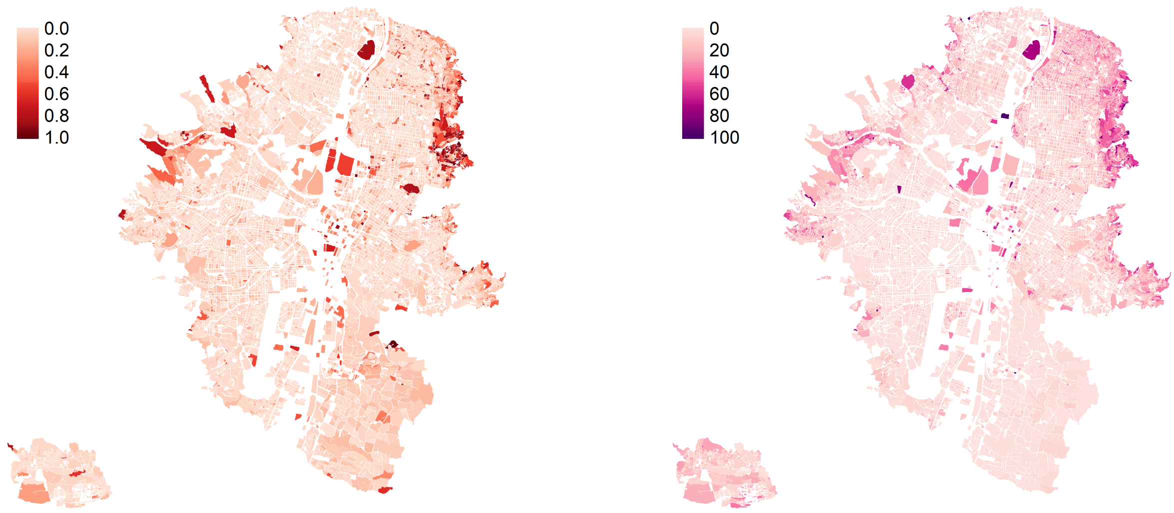
One of the frequently examined features of VIS projects is their location. It is common for these projects to be developed in locations where land prices are low. This reduces land developer's production costs, allowing for a greater supply of subsidized housing. However, the location of these projects can force households to move away from the opportunities offered by the city and from their family and neighbors. It is important then to provide additional elements of analysis to judge public housing provision policies, especially concerning their effects on the territory.

[2]With a population of approximately 2.4 million inhabitants and a 7% share of the national GDP, Medellin is the second most important city in Colombia. Medellín is located in the northwest of the country, in the middle of a narrow valley between the central and western Andes mountain ranges and is crossed from north to south by a river that bears the same name.

[3]Medellín Cómo Vamos is a private alliance that examines the evolution of different socioeconomic indicators of the city of Medellín using information from the National Census of the year 2018 and the annual Quality of Life Survey of Medellín.

[4]Accessibility measures how easy is to access to the opportunities offered by the entire city from a specific location.

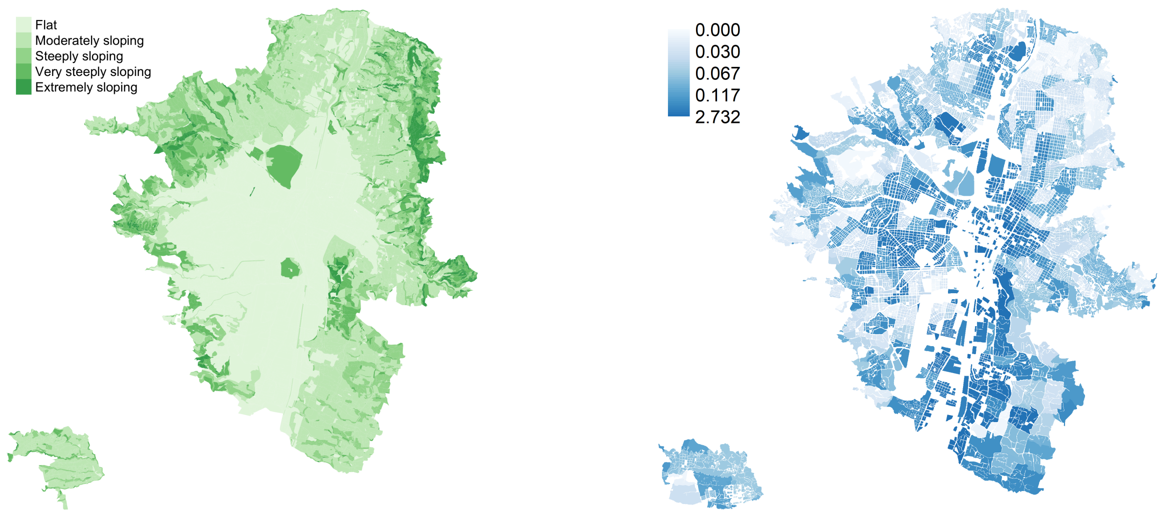
Figure 1: Informal housing and poverty



(a) Informal housing (b) Poverty

Source: Author's calculations. Colombian Census, 2018.

Figure 2: Labor accessibility and Slope

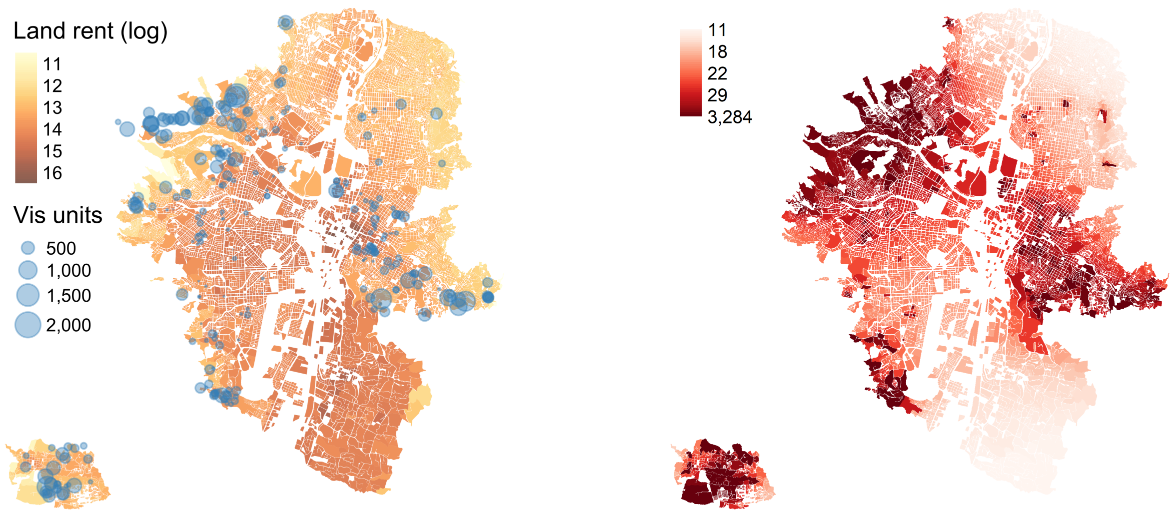


(a) Topography (b) Job accessibility

Source: Author's calculations. POT, 2014, OD 2017.

Figure 3a shows the location of the VIS projects built in Medellín between 2004 and 2018, along with their size and the average land value per square meter in 2020.Although VIS projects can be found throughout the city, the most extensive projects are concentrated to the center-west in a sector known as Pajarito. There is also an important concentration of projects in the center-east, in the extreme southwest in the district of San Antonio de Prado, and in the south in Belén neighborhood. Another group of smaller-scale projects can be found in the city center. It is observed then that the VIS projects are concentrated precisely in areas with low land values per square meter, low accessibility, and especially in areas with a high incidence of informal housing.

Figure 3: Spatial distribution of social housing



(a) Social housing locations and land value

(b) Social housing exposition

Source: Author's calculations. Camacol, 2020.

4 Empirical Strategy

4.1 Geography, unit of analysis, and sample

The data of households and their housing characteristics is obtained from the Colombian National Census of 2018. The data is georeferenced at census block level, which is the smallest geographical area defined in the statistical operation of the survey. Therefore, in our basic estimation exercise, the census block will be used as the unit of analysis. For Medellin, we count with a universe of 11,201 census blocks which allows to perform an analysis with high spatial density. It also allows us to limit measurement errors that may arise when the effects of VIS projects depend on the distance and large spatial areas are used, such as neighborhoods or census tracts.

Because the construction of new public housing directly affects quality indicators inside the census block, our sample will be limited to locations that do not have any projects inside their borders, and that simultaneously are within a distance of 400 meters or less from a VIS project. With this procedure, we seek to reflect a positive probability of having been treated but, for different reasons, having greater or lesser exposure to this treatment. Our final sample reaches a size of 4,619 blocks. Figure 5a identifies blocks in whose borders are present new housing projects, blocks that are indirectly exposed to VIS housing (our sample), and blocks far from any project. Despite their small sizes, census blocks have irregular shapes and different sizes. To check the robustness of our results, we also use uniform grids of $70 \times 70\ m^2$ as the geographical unit of analysis. In this case the total sample reaches a size of 6,062 units.

4.2 Data and variables

To build the indicators of exposure to treatment, this paper uses data from public housing projects built in Medellin between 2004 and 2018. The data was generously provided by the Colombian Chamber of Construction (Camacol, for its Spanish acronym). For each public housing project, we count with information of the precise location, the number of blocks, apartments, and square meters. Our basic treatment variable is given by an indicator of exposure to VIS housing projects which is based in the accesibility inidex proposed by Hansen (1959):

$$A_i = \sum_{s=1}^{S} \frac{a_s}{d_{is}} \tag{1}$$

where A_i represents the intensity of the exposure at location i, a_s is the fraction of VIS housing (usually a fraction of the total square meters built in the city) at location s, and d_{is} is the distance between location i and location s. According to the indicator, it will be observed that location i will experience a greater intensity of exposure to VIS projects when it is closer to areas with a high incidence of new housing projects. Figure 3b shows the spatial distribution of the VIS housing exposure index. As expected, the highest levels of exposure are concentrated in the center-west, the center-east, and the southwest zones of the city.

Using the National Census of Colombia for 2018, an informal housing index is constructed as the main outcome variable. This index is a reduced version of the informal housing indicator proposed by UN-Habitat (2003). According to our index a housing is considered to be precarious or informal when exhibits one or more of the following characteristics: overcrowding, lack of an adequate connection to water and sewage and precarious building materials. A reduced version of our index is also used and in this case a housing is considered to be precarious only if it is overcrowded or built with precarious materials, aspects that depend more directly on household's decisions.

We also estimate the effects of public housing on the individual components of the informal housing index, the incidence of crime, the multidimensional poverty index, and the percentage of the migrant population. From census data, it is possible to determine if a person migrated in the last year or the previous five years. Crime data was obtained from the open data repository of the Administration of Medellin (MedData). This data describes the crime (in our exercise robberies against people), the geographical coordinate of occurrence, and the time of the event. The multidimensional poverty index[5] was obtained from the Departamento Administrativo Nacional de Estadísticas (DANE, for its Spanish acronym) public micro-data repository.

In our exercise we use an extensive group of control variables which include: the unemployment rate, the dependency rate, the average years of education, the average land rents, accessibility to employment opportunities, accessibility to educational establishments, accessibility to health centers, the slope of the terrain, the quality of the roads, the distances to the stations of the mass transportation system, the distance to the main roads, and the geological suitability of the land. The demographic and labor market indicators were built using information of National Census data. The distances to the mass transportation system stations, the distances to main roads, the quality of the streets, and average land rents were obtained from the 2014 Medellin's Zoning Plan (POT, for its Spanish acronym). Finally, accessibility indexes were calculated from the 2017 Origin and Destination survey of the Aburra Valley Metropolitan Area.

4.3 Identification Strategy

The purpose of this exercise is to estimate the effect of new public housing projects on housing quality, crime, migration, and poverty in the neighborhood. To do this, a first approach is to estimate the parameter β in the following equation:

$$y_i = \beta z_i + \delta' X_i + \varepsilon_i \tag{2}$$

where i indexes neighborhoods (which in our case are census blocks or grids), y_i is an outcome variable, z_i is the indicator of exposure to VIS projects and X_i is the vector of control variables. However, the estimation of β in equation 2 through ordinary least squares is expected to produce a biased and inconsistent estimator $\hat{\beta}$. First, VIS projects locations and housing quality indicators simultaneously depend on non observable characteristics like community organization, neighborhood and family support networks, future infrastructure and investment projects to be built in the area, causing an omitted variable bias. For example, neighborhoods with organized and proactive communities can generate collective actions to improve facades, legalize tenure, and manage the provision of new quality housing. Second, VIS housing projects are usually built in areas with high levels of precarious housing and poverty, causing a reverse causality bias.

More technically, in equation 2 the treatment variable z_i and the error term ε_i are correlated, and therefore $\hat{\beta}$ does not reflect the causal effect of interest. To overcome these identification problems arising from the endogeneity of z_i, we use an instrumental variables identification strategy. The regression equations for the first stage and the reduced form are given by:

[5] The multidimensional poverty index is made up of 15 indicators organized into 5 dimensions that seek to capture the welfare conditions of households: education, childhood and youth, health, work, and access to public services and housing conditions. A household is considered multidimensionally poor when they have a level of deprivation in 33% of the 15 weighted indicators.

$$z_i = \rho_1 w_i + \gamma_1' \boldsymbol{X}_i + v_{1i} \quad (3)$$

$$y_i = \rho_2 w_i + \gamma_2' \boldsymbol{X}_i + v_{2i} \quad (4)$$

where w_i is an instrumental variable that must meet certain conditions that will be discussed later. The causal effect of z_i on y_i can be identified from the following expression:

$$\beta = \rho_1/\rho_2 = cov(y_i, \tilde{w}_i)/cov(z_i, \tilde{w}_i) \quad (5)$$

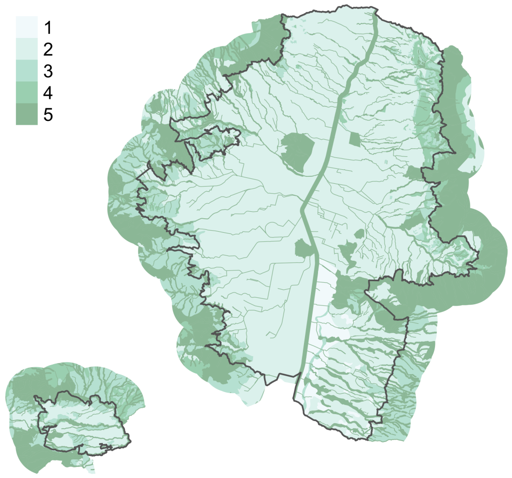
where $\tilde{w}_i$ is the residual obtained from the regression of w_i on the vector of covariates $\boldsymbol{X}_i$. The sample analog of the right-hand side of 5 is the instrumental variables estimator. The instrument must meet two identification conditions. First, the instrument must have a high explanatory power over the treatment variable. Second, the instrument must not be correlated with ε_i. This is known as the exclusion restriction and implies that the instrument is independent of the potential results and that only affects the outcomes through the treatment variable z_i. For our estimation we will use the geological suitability of the land around each census block as an instrumental variable. Geological variables such as access to bedrock, seismic risk, landslide hazard or soil quality have proven to be appropriate instruments as they relate to construction cost or cost of density (Rosenthal and Strange, 2008; Combes et al., 2010; Rosenthal and Strange, 2020). Other examples that use geological variables as an instrument include Di Addario (2011); Hawley (2012); Curci (2015); Liu (2017) and Duranton and Turner (2018).

A geological restriction for construction in land around a census block is expected to limit the supply of new public housing around this block. Also it can be thought that conditional on land prices and the geological suitability of land within the census block, the geological suitability of land around this block is not related with non-observable characteristics that affect informal housing within the block. For example, it is reasonable to think that community organizations are related with housing conditions in the neighborhood but not with the geological suitability of land in surrounding areas. At the same time, it is reasonable to think that the geological suitability in surrounding areas can affect the size of VIS housing projects. In other words, it is reasonable to think that this instrument meets the exclusion restriction and the relevance condition. Next we explain in detail the construction of our instrumental variable.

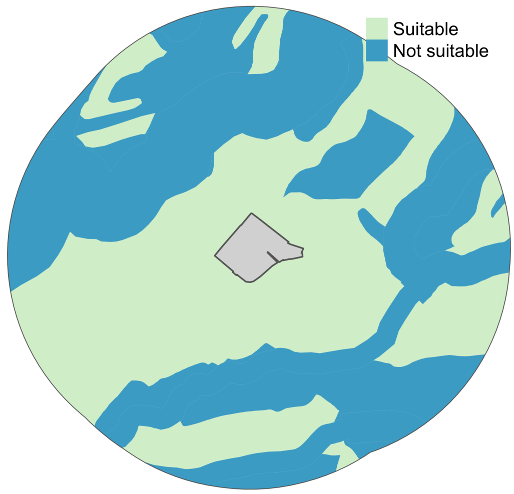
4.4 Instrument construction

Information on geological suitability of land for construction will be used to build our instrument. Geological data of Medellin was obtained from the georeferenced layers of the 2006 zoning plan . These layers define a series of polygons that are classified according to the level of geological suitability of the land. For polygons in categories A, B, and C there are favorable geological conditions for construction. For polygons in a category D there are geological restrictions. Finally, polygons in category E are defined as not usable for construction. As we can see from Figure 4a land without favorable conditions for construction is concentrated in the periphery around hillside areas of the city, whereas land with favorable conditions for construction is concentrated in the middle of the valley.

Figure 4: Geology and surroundig area definition



(a) Geology



(b) Surrounding area

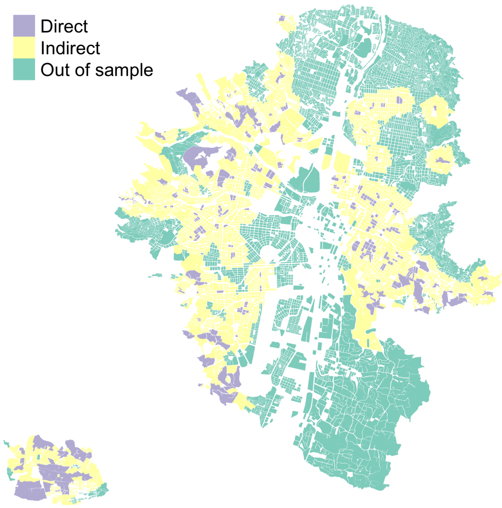
Source: Author's calculations. POT, 2014.

Grouping A, B, and C categories into a single category called "high geological suitability" and D and E categories into another single category called "low geological suitability", we define our instrument w_i as a binary variable which takes the value of one if low geological suitability prevails in the land around the census block, and takes the value of 0 if high geological suitability prevails in the land around the census block.

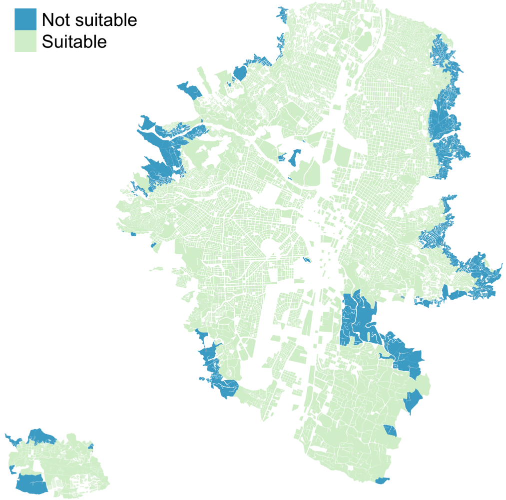
Figure 4b illustrates the construction of the instrument. The census block is represented by the gray polygon, the land around the block is defined by the buffer, and the areas of the two land categories are represented in different colors. The category that occupies the largest area defines the prevailing geological suitability and therefore the value of our instrument. It is important to clarify that in our regressions the geological suitability of land inside the block itself is incorporated as a control variable. In this way, we avoid the direct relationship between the instrument and the outcomes.

Using a buffer size of 400 meters, Figure 5b shows the spatial distribution of the instrument. As expected, the map indicates a concentration of non-suitable land for construction around the urban fringes in the steepest areas of the city (see Figure 2a). These places also largely coincide with zones of high incidence of informal housing and VIS housing projects.

Figure 5: Sample and instrument



(a) Sample definition



(b) Instrument distribution

Source: Author's calculations. POT, 2014, Camacol, 2020.

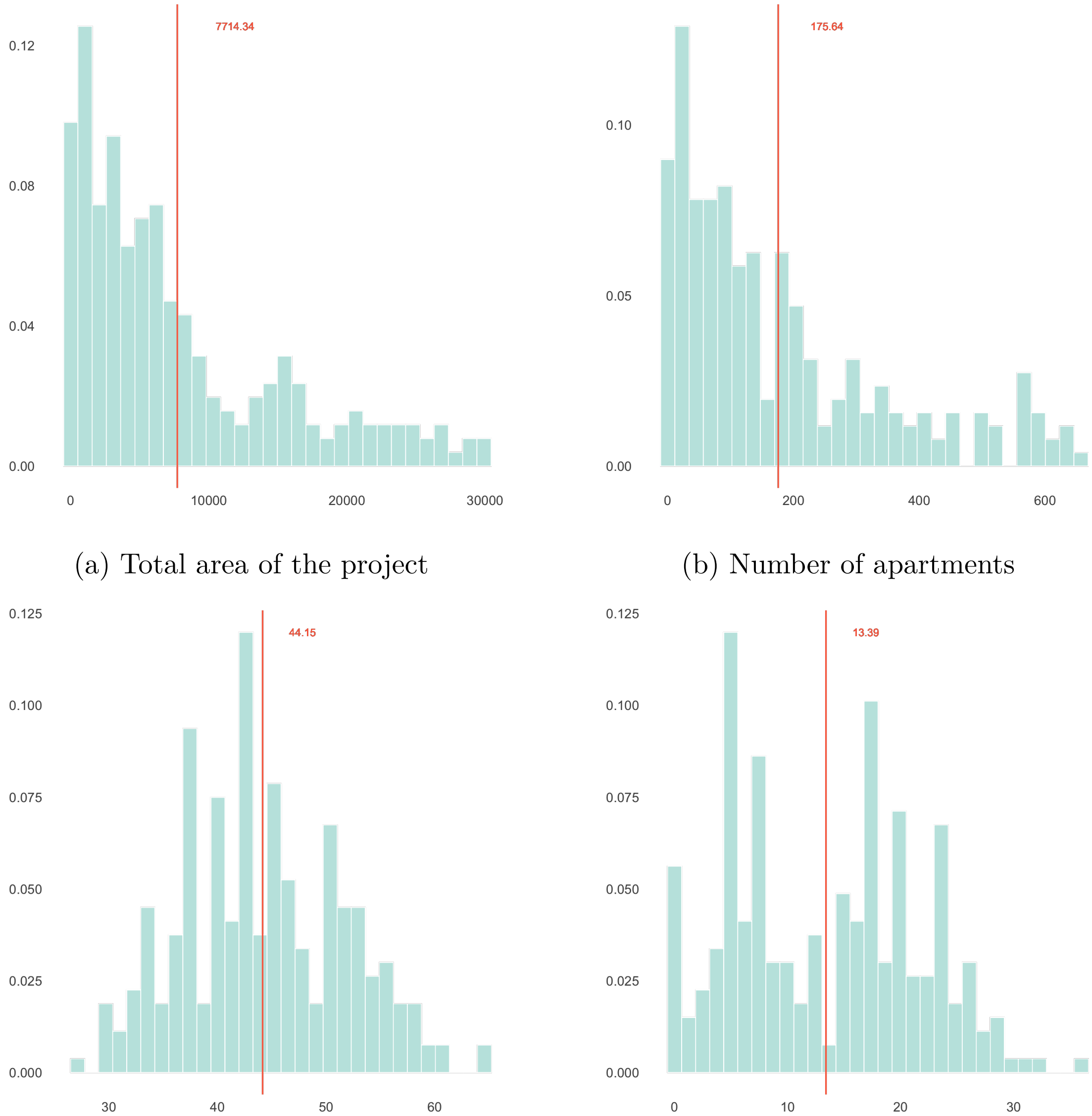
5 Descriptive statistics

Between 2004 and 2018, 268 VIS housing projects were developed in Medellín containing 57,185 homes and 2,501,730 square meters. According to Figures 6a and 6b, the average project contains 175 apartments, equivalent to a private habitable area of 7,714 square meters. There is also a high level of dispersion manifested in the coexistence of projects of a single housing unit with mega projects with 600 apartments and built areas above 30,000 square meters.

The average housing unit is 44.15 m^2, and the average building height is 13.30 floors, reflecting high structural and residential densities of the projects. It is also can be seen that there are two groups of projects in terms of structural density: one group is characterized by buildings with an average height of 5 floors, and the other is characterized by buildings with an average height of 20 floors (see Figures 6c and 6d).

As previously highlighted, the projects are located on the city's outskirts, in areas with low land values and low accessibility to labor markets. The average distance of the projects to the city center is 4,419.04 meters, which given the city's high population density and limited territorial extension, implies a relative disconnection of the public housing projects from the rest of the city. It also should be noted from Figure 3b and Figure 4a, that in areas of high exposure to VIS housing, there are also important variations in the geological suitability of the land with a concentration of non-suitable land in the urban edges towards the center-west, central east, and north-east, the steepest areas of the city (see Figure 2a).

Figure 6: Social housing characteristics



(a) Total area of the project

(b) Number of apartments

(c) Apartment area

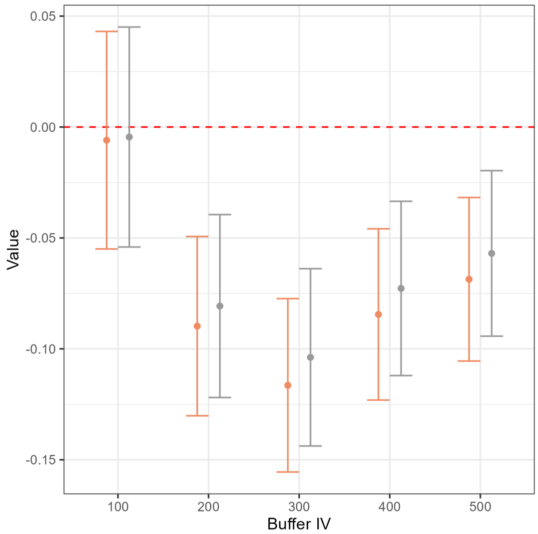
(d) Floors

Source: Author's calculations. Camacol, 2020.

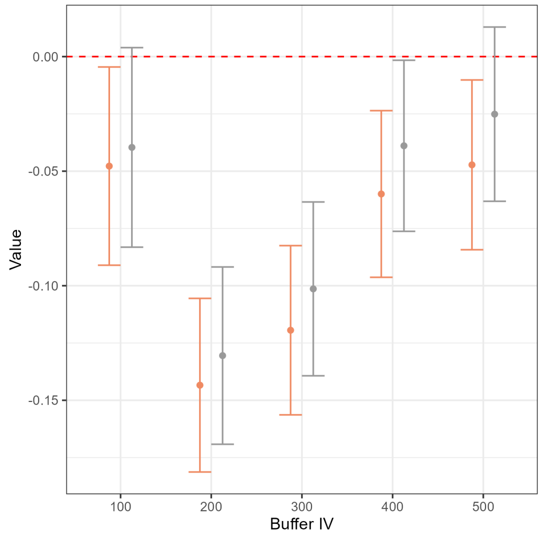
6 Results

Before presenting causal estimates, estimations of the first stage (equation 3) are shown to verify the instrument's relevance. In Figure 7, we present the results for both the census blocks sample and the grid sample, revealing a consistent negative relationship between the exposure to VIS housing (both to square meters and apartments) and our binary instrument (which, as mentioned before, takes the value of one when low geological suitability prevails in the land around a census block). This suggests that a worse geological suitability decreases the construction of VIS housing.

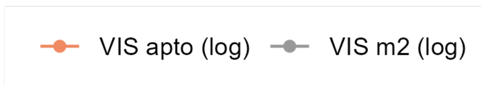
Figure 7: Instrument relevance



(a) Census track (Robust)



(b) Grid (Robust)



Source: Author's calculations. POT, 2014, Camacol, 2020; Census, 2018.

Using census blocks as the unit of analysis, the relationship between the instrument and the treatment variable is statistically significant for different buffer sizes around the block except for buffers of 100 meters (see Figure 7a). Using a uniform grid as the unit of the analysis, the relationship between the instrument and the treatment variable is also statistically significant for different buffer sizes, except when simultaneously buffers have a size of 100 meters and 500 meters and the treatment variable is constructed using square meters (see Figure 7b). We also run weak instrument tests revealing that our instrument have enough predictive power (see Table 2 in Appendix).

Next, we estimate the effects of new VIS housing on different outcomes. In Figure 8a, we systematically observe that a census block indirectly exposed to a higher level of new VIS housing projects presents a lower level of informal housing. For example, for a buffer of 400 meters, it is observed that a 10% increase in exposure (both in square meters built and in the number of apartments) reduces the housing informality rate by approximately 4 pp. This implies that when a VIS project of average size is built at 300 meters of distance of the block, the indirect exposure indicator rises 3.9% above the average exposure, which in turn reduces 1.55 pp the informality rate of housing on the block. These results reveal that new VIS housing projects not only directly reduce the quantitative housing deficit but also indirectly reduce the qualitative housing deficit in their areas of influence, adding a new dimension to the improvement and transformation of the urban habitat.

Our results also show that new VIS housing reduces poverty in the neighborhood, an expected result given that housing conditions are an important component of any multidimensional poverty index. (Figure 8b). In this case a 10% increase in exposure to VIS projects reduces the multidimensional poverty index by around 5 pp. Again, public housing besides directly reducing poverty by providing housing solutions to people who had never had their own homes, indirectly reduces poverty through the indirect reduction of qualitative housing deficit.

Regarding the components of the informal housing index, Figure 8c shows that new VIS projects led to an improvement in the quality of housing materials. After controlling for all the covariates, and isolating exogenous variations in new public housing, this result is closely related with the demonstration effect previously mentioned and which sustains that households and investors can gain confidence and thus invest, once they see public investments in the neighborhood (Schwartz et al., 2006, see).

Figures 8e and 8f, show that new VIS projects led to an increase in the proportion of houses connected to water and sewerage infrastructure. This is explained by the urban and habitat standards imposed to VIS housing projects. VIS projects must offer and adequate connection to water, sewage, and electricity infrastructure. To comply with these obligations, developers and urban authorities often have to extend the public utilities network in the territory, thus making cheaper, the connection of existing houses to infrastructure. Finally, Figure 8d shows that new VIS housing projects did not generate statistically significant changes in overcrowding.

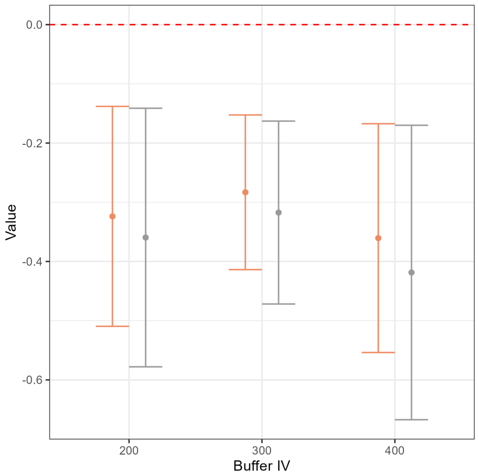
Next we estimate the effects of a higher exposure to VIS housing on theft rate, land values, migration rate, and unemployment rate. Figure 9a shows that a higher exposure to VIS housing reduces the theft rate. Although there is mixed evidence in the literature about the effects of new housing on crime (Sandler, 2017), our findings are consistent with previous results in contexts with high spatial segregation (Freedman and Owens, 2011).

Consistent with previous evidence for both developed and developing countries, new VIS housing projects led to an increase in land rents (see Figure 9c). Figure 9d shows that a higher exposure to VIS housing projects is associated with a lower proportion of migrants in the neighborhood, suggesting that new VIS housing generates gentrification. Finally, Figure 9b reveals that a greater exposure to VIS housing did not change unemployment rates.

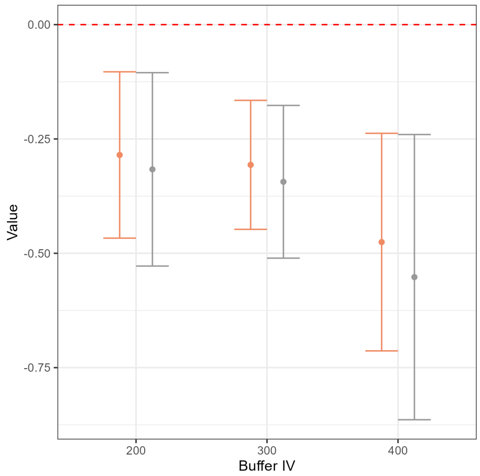
7 Robustness analysis

As mentioned before census blocks have different shapes and sizes, which can generate measurement errors and consequently estimation bias. To address the previous issue, next we run causal regressions using a uniform grid as the unit of analysis. Figure 10 reveals, as before, that a higher indirect exposure to new VIS housing projects reduce informal housing, multidimensional poverty, and theft rates (see panel, Panels 10a, 10b, and 10g), and increase land rents (see Panel 10i).

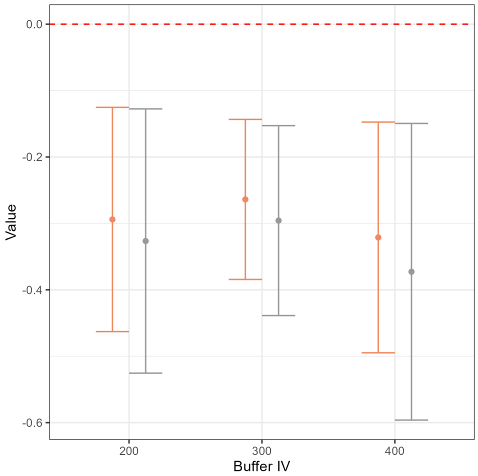
Figure 8: Estimation results (Census blocks)



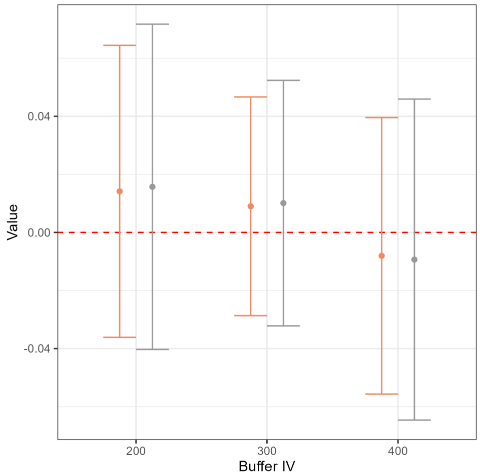
(a) Informal housing (% Total)



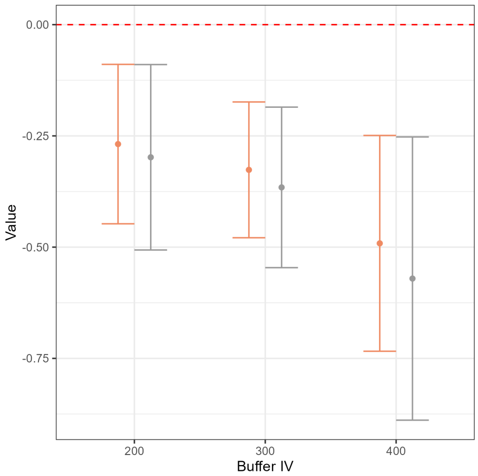
(b) Poverty



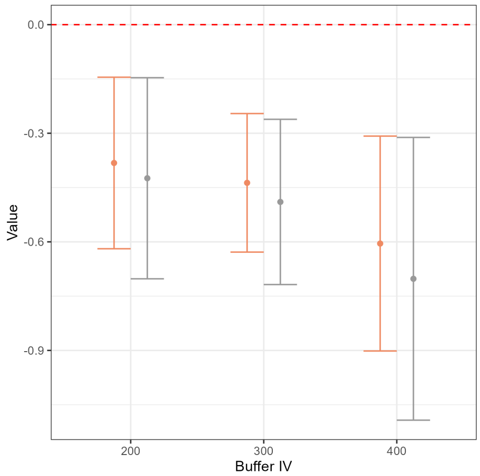
(c) Walls



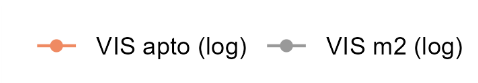
(d) Crowding



(e) Water

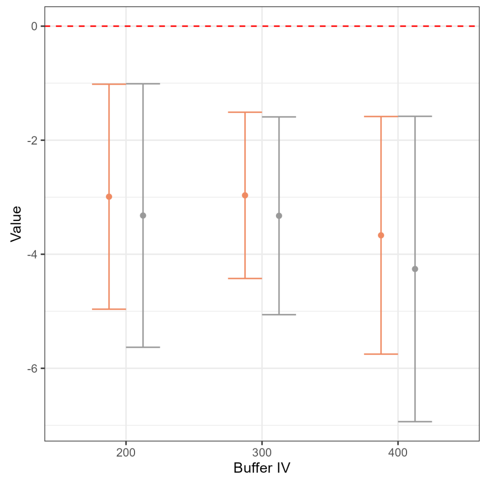


(f) Sanitation

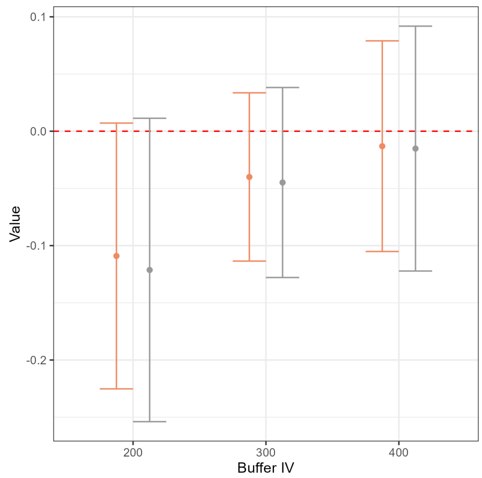


Source: Author's calculations. POT, 2014, Camacho, 2020; Census, 2018.

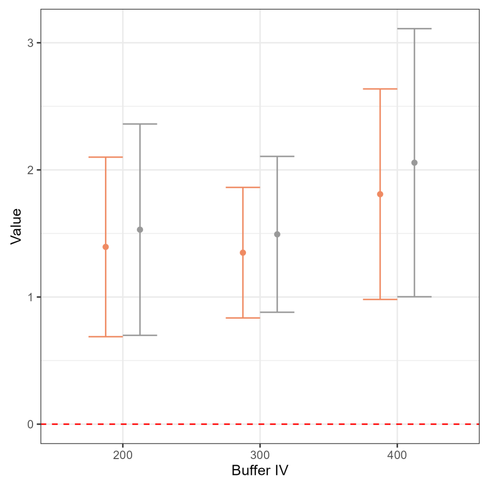
Figure 9: Estimation results (Census track)



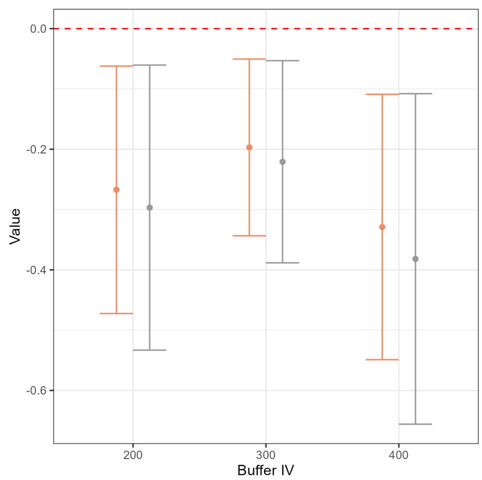
(a) Thefts (1000 hab.)



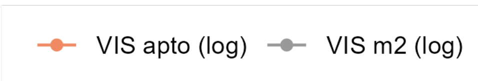
(b) Unemployment rate



(c) Land rent (in logs)

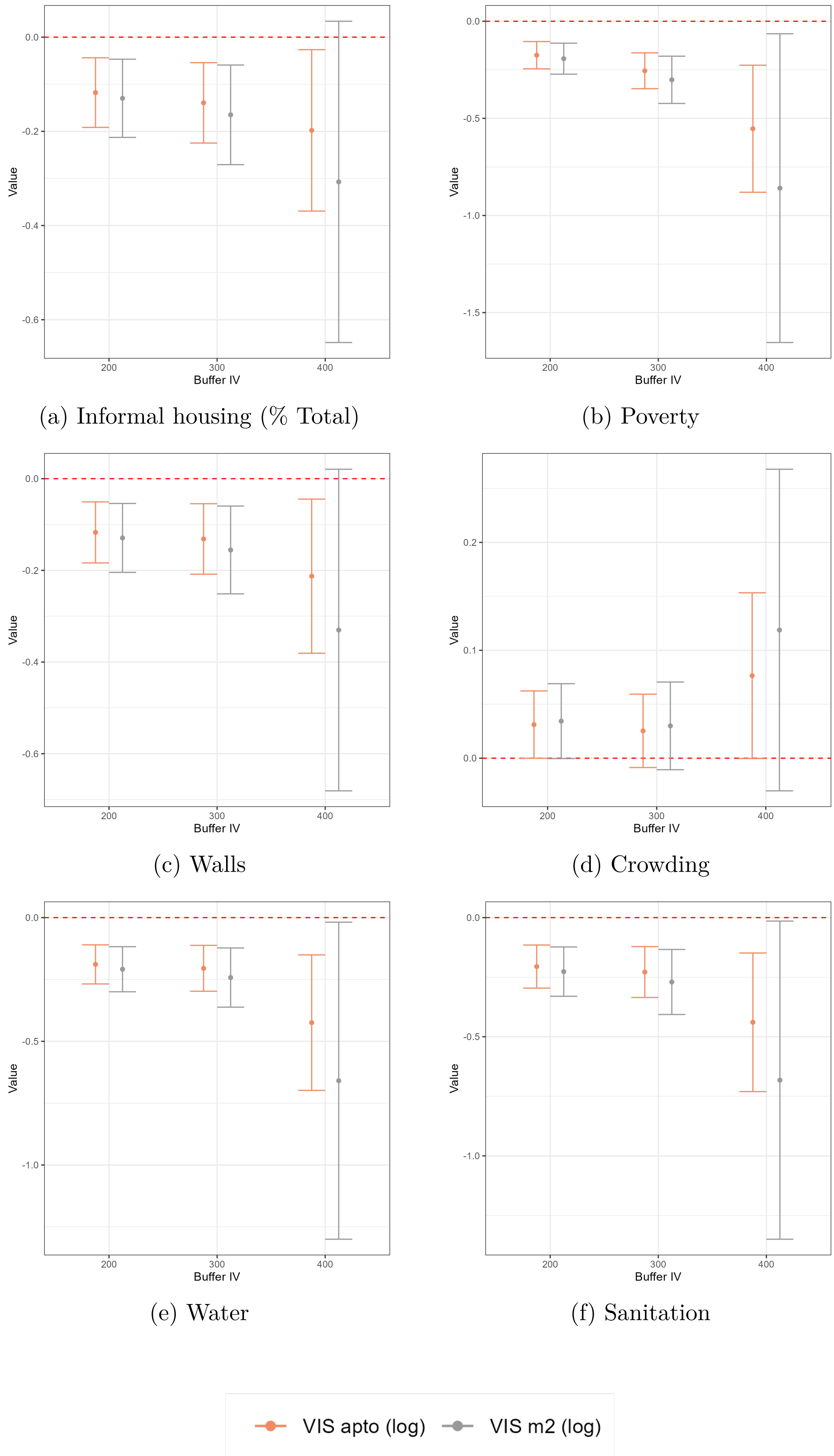


(d) Migration rate



Source: Author's calculations. POT, 2014, Camacol, 2020; Census, 2018.

Figure 10: Estimation results (Grid)



(a) Informal housing (% Total)

(b) Poverty

(c) Walls

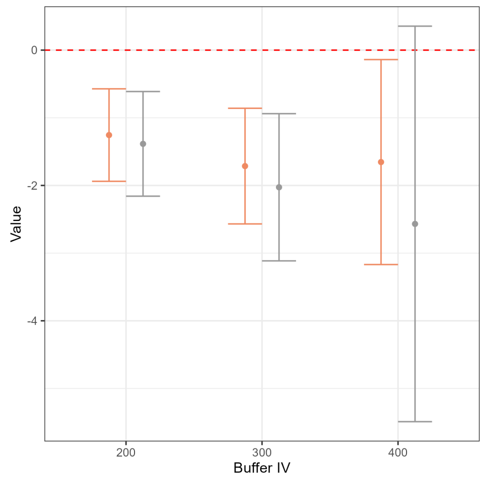
(d) Crowding

(e) Water

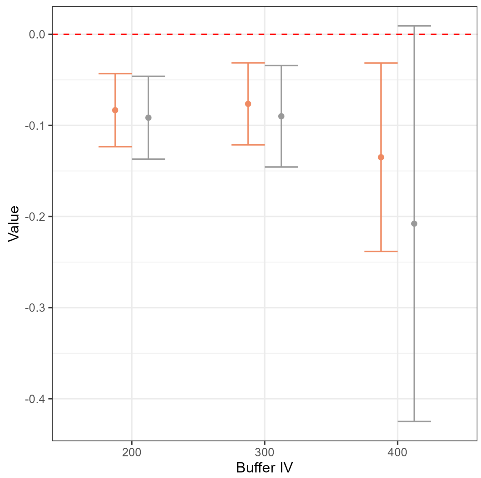
(f) Sanitation

Source: Author's calculations. POT, 2014, Camacol, 2020; Census, 2018.

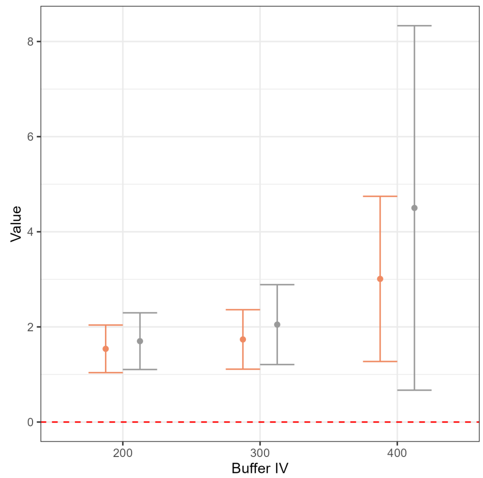
Figure 10: Estimation results (Grid)



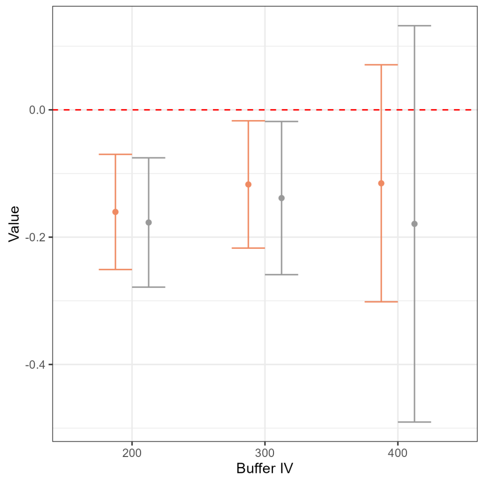
(g) Thefts (1000 hab.)



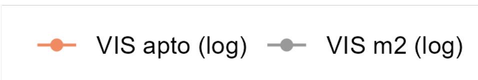
(h) Unemployment



(i) Land value(log)



(j) Migration

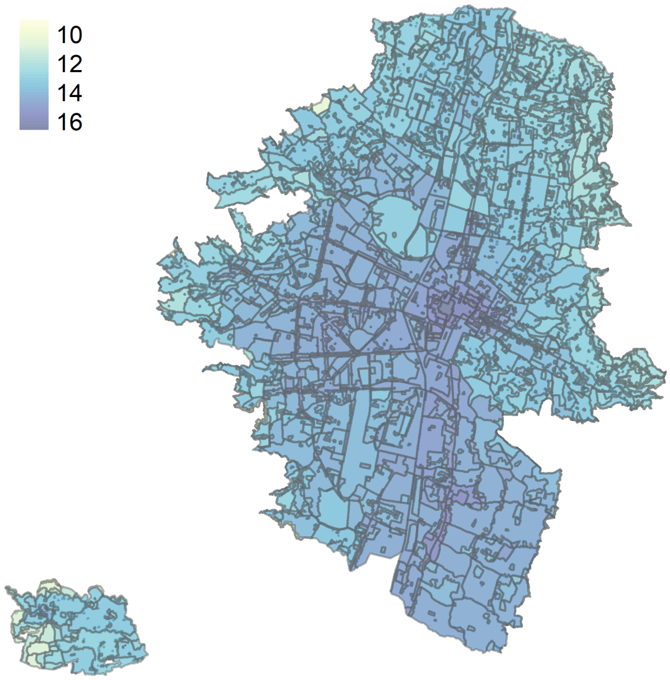


Source: Author's calculations. POT, 2014, Camacol, 2020; Census, 2018.

However, in contrast with the evidence presented using the census blocks as the unit of analysis, in this case a higher exposure to new VIS housing projects leads to lower unemployment rates (see Figure 10h). Again this suggest that new VIS housing generates gentrification in their areas of influence by replacing groups of migrants with high unemployment rates for non-migrants with low unemployment rates. Summing up, our results are robust for different exposure measures, for different sizes of the areas surrounding the block (i.e. different buffer sizes) and for different definitions of the unit of analysis.

Given the spatial nature of the information, groups of closely related census blocks may be present. To address this issue we run causal regressions assuming clustered standard errors. We consider that our information is grouped by the geoeconomic zones established in the 2014 zoning plan of Medellín . Geoeconomic zones are defined to guide the calculations of land rents in relatively homogeneous areas helping in this way to determine the urban obligations for households in different parts of the city.

Figure 11: Geoeconomic Zones



Source: Alcaldía de Medellín. Color shows the land value per square meter in log.

As expected, the estimated standard errors are larger under the assumption of clustered errors, which makes the instrument lose relevance in the 100, 400 and 500 meter buffers (see Figure 12). However, the instrument is still relevant for 200 and 300 meter buffers. The appendix (section 8) shows estimation results under clustered standard errors and for buffers between 200 and 300 meters. Figures 13 and 14 reveal that the main conclusions of our analysis remain unchanged.

8 Concluding remarks

The sustained growth of cities and the persistence of high poverty rates in developing countries have led to high quantitative housing deficits. To respond to this challenge, the authorities have promoted public housing programs that mainly benefit low-income households. These projects are usually located in areas with low urban development and low land rents, leading to important changes in the territory. In this paper we estimate the effects of new VIS housing projects on different outcomes in the neighborhood in locations characterized by high levels of informal housing. We regress informal housing indexes against a measure of exposition to new public housing projects, and a rich set of economic and geographical controls. We also use the geological quality of the land as an instrumental variable for our measure of exposition to new housing projects.

Our results reveal that new VIS housing projects indirectly reduce the qualitative housing deficit in their areas of influence. This is because new VIS projects led to an improvement in the quality of housing materials, a result that is closely related with the demonstration effect which sustains that households and investors can gain confidence and thus invest, once they see public investments in the neighborhood (Schwartz et al., 2006, see). Additionally, new VIS projects led to an increase in the proportion of houses connected to water and sewerage infrastructure. Given that VIS projects must offer and adequate connection to water, sewage, and electricity infrastructure, developers and urban authorities often have to extend the public utilities network in the territory, making easier the connection of existing houses to infrastructure.

From a public policy perspective, our results contribute to discussing on the indirect benefits of public housing policies in the developing world. In particular, we confirm that although the main goal of these policies is to directly provide housing solutions to low income households, additional gains are obtained trough the improvements in several dimensions in the territory.

References

Agnew, S. (2010). The impact of affordable housing on communities and households. *Minnesota Housing Finance Agency*.

Alonso, J. M., Andrews, R., and Jorda, V. (2019). Do neighbourhood renewal programs reduce crime rates? Evidence from England. *Journal of Urban Economics*, 110(November 2018):51–69.

Alzúa, María Laura, A.-J. C. G. y. G.-C. (2016). Housing Subsidies, Labor Supply and Household Welfare. Experimental Evidence from Argentina.

Asquith, B. J., Mast, E., and Reed, D. (2021). Local effects of large new apartment buildings in low-income areas. *The Review of Economics and Statistics*, pages 1–46.

Bailey, P. (2020). *Housing and health partners can work together to close the housing affordability gap*. JSTOR.

Baum-Snow, N. and Marion, J. (2009). The effects of low income housing tax credit developments on neighborhoods. *Journal of Public Economics*, 93(5-6):654–666.

Camacho-González, Adriana, C.-L. J. E. y. S.-T. F. (2022). Un nuevo comienzo: El impacto del Programa Vivienda Gratuita sobre la calidad de vida de los hogares beneficiarios.

Chagas, A. L. S. and Rocha, G. M. (2019). Housing program and social conditions impact: Evidences from Minha Casa Minha Vida program lotteries in Brazil. Working Papers, Department of Economics 2019_40, University of São Paulo (FEA-USP).

Combes, P.-P., Duranton, G., Gobillon, L., and Roux, S. (2010). Estimating agglomeration economies with history, geology, and worker effects. In *Agglomeration economics*, pages 15–66. University of Chicago Press.

Curci, F. (2015). The taller the better? agglomeration determinants and urban structure.

Daminger, A. (2021). Subsidies to homeownership and central city rent. Technical report, BGPE Discussion Paper.

DANE (2021). Boletín técnico de déficit habitacional. encuesta nacional de calidad de vida (ecv) 2020.

Daude, C; Fajardo, G. B. P. E. R. G.-C. S. P. V. J. (2017). *RED 2017. Crecimiento urbano y acceso a oportunidades: un desafío para América Latina.* CAF.

Departamento Nacional de Planeación (2021). Concepto favorable a la nación para contratar un empréstito externo con la banca multilateral hasta por usd 100 millones, o su equivalente en otras monedas, destinado a financiar el programa de vivienda resiliente e incluyente en colombia.

Di Addario, S. (2011). Job search in thick markets. *Journal of Urban Economics*, 69(3):303–318.

Diamond, R. and McQuade, T. (2019). Who wants affordable housing in their backyard? an equilibrium analysis of low-income property development. *Journal of Political Economy*, 127(3):1063–1117.

Ding, L., Nie, P., and Sousa-Poza, A. (2022). Housing conditions and health in urban china.

DNP (2009). Lineamientos para la consolidación de la política del Mejoramiento Integral de Barrios MIB.

Duranton, G. and Turner, M. A. (2018). Urban form and driving: Evidence from us cities. *Journal of Urban Economics*, 108:170–191.

Ellen, I. G., Schill, M. H., Susin, S., and Schwartz, A. E. (2001). Building Homes, Reviving Neighborhoods: Spillovers from Subsidized Construction of Owner-Occupied Housing in New York City. *Journal of Housing Research*, 21(2):185–216.

Ellen, I. G., Schwartz, A. E., Voicu, I., and Schill, M. H. (2007). Does federally subsidized rental housing depress neighborhood property values? *Journal of Policy Analysis and Management*, 26(2):257–280.

Eriksen, M. D. and Rosenthal, S. S. (2010). Crowd out effects of place-based subsidized rental housing: New evidence from the lihtc program. *Journal of Public Economics*, 94(11-12):953–966.

Fertig, A. R. and Reingold, D. A. (2007). Public housing, health, and health behaviors: Is there a connection? *Journal of Policy Analysis and Management: The Journal of the Association for Public Policy Analysis and Management*, 26(4):831–860.

Franklin, S. (2020). Enabled to work: The impact of government housing on slum dwellers in south africa. *Journal of Urban Economics*, 118:103265.

Freedman, M. and Owens, E. G. (2011). Low-income housing development and crime. *Journal of Urban Economics*, 70(2-3):115–131.

Freeman, L. (2003). The Impact of Assisted Housing Developments on Concentrated Poverty. *Housing Policy Debate*, 14:103–142.

Funderburg, R. and MacDonald, H. (2010). Neighbourhood valuation effects from new construction of low-income housing tax credit projects in Iowa: A natural experiment. *Urban Studies*, 47(8):1745–1771.

Gechter, M. and Tsivanidis, N. (2020). Spatial Spillovers from Urban Renewal: Evidence from the Mumbai Mills Redevelopment.

González-Pampillón, N. (2022). Spillover effects from new housing supply. *Regional Science and Urban Economics*, 92:103759.

Hansen, W. G. (1959). How accessibility shapes land use. *Journal of the American Institute of planners*, 25(2):73–76.

Hawley, Z. B. (2012). Does urban density promote soci al interaction? evidence from instrumental variable estimation. *Review of Regional Studies*, 42(3):223–248.

Kumar, T. (2019). The human capital effects of subsidized homeownership: Evidence from a natural experiment in Mumbai.

Liu, S. (2017). Agglomeration, urban wage premiums, and college majors. *Journal of Regional Science*, 57(4):611–630.

Lopez, Maria; Sanchez, F. (2021). Evaluación de impacto del programa de vivienda "mi casa ya".

Matte, T. D. and Jacobs, D. E. (2000). Housing and health—current issues and implications for research and programs. *Journal of urban health*, 77(1):7–25.

Medellín Cómo Vamos (2020). Informe de calidad de vida de medellín.

Minvivienda (2015). Decreto 0428 del 2015 por el cual se implementa el programa de promoción de acceso a la vivienda de interés social "mi casa ya".

Olsen, E. O., Tyler, C. A., King, J. W., and Carrillo, P. E. (2005). The Effects of Different Types of Housing Assistance on Earnings and Employment. *Cityscape: A Journal of Policy Development and Research*, 8(2):163–187.

Picarelli, N. (2019). There is no free house. *Journal of Urban Economics*, 111:35–52.

Rosenthal, S. S. and Strange, W. C. (2008). The attenuation of human capital spillovers. *Journal of Urban Economics*, 64(2):373–389.

Rosenthal, S. S. and Strange, W. C. (2020). How close is close? the spatial reach of agglomeration economies. *Journal of economic perspectives*, 34(3):27–49.

Sandler, D. H. (2017). Externalities of public housing: The effect of public housing demolitions on local crime. *Regional Science and Urban Economics*, 62:24–35.

Santiago, A. M., Galster, G. C., and Tatian, P. (2001). Assessing the property value impacts of the dispersed hounsing subsidy program in Denver. *Journal of Policy Analysis and Management*, 20(1):65–88.

Saraswat, D. (2021). Labor market impacts of exposure to affordable housing supply: Evidence from the low-income housing tax credit program. *Available at SSRN 4059439*.

Schwartz, A. E., Ellen, I. G., Voicu, I., and Schill, M. H. (2006). The external effects of place-based subsidized housing. *Regional Science and Urban Economics*, 36(6):679–707.

Sinai, T. and Waldfogel, J. (2005). Do low-income housing subsidies increase the occupied housing stock? *Journal of public Economics*, 89(11-12):2137–2164.

Susin, S. (2005). Longitudinal Outcomes of Subsidized Housing Recipients in Matched Survey and Administrative Data. *Cityscape: A Journal of Policy Development and Research*, 8(2):189–218.

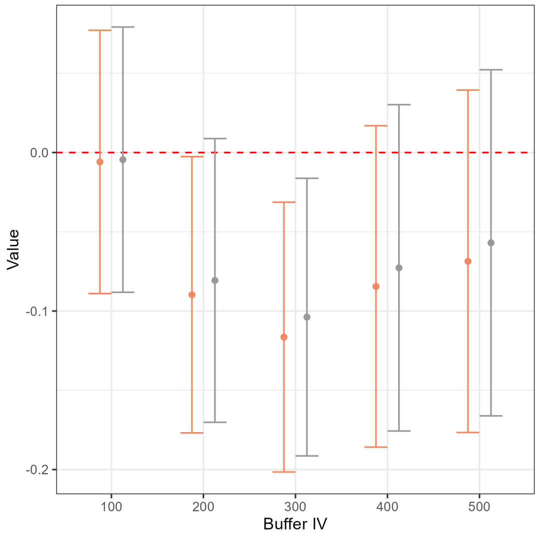
UN-Habitat (2003). The challenge of slums: Global report on human settlements.

Varady, D. P. (1982). Indirect benefits of subsidized housing programs. *Journal of the American Planning Association*, 48(4):432–440.

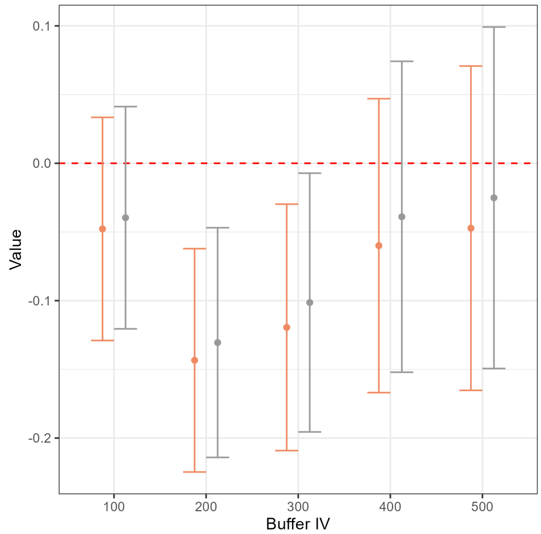
Voith, R., Liu, J., Zielenbach, S., Jakabovics, A., An, B., Rodnyansky, S., Orlando, A. W., and Bostic, R. W. (2022). Effects of concentrated lihtc development on surrounding house prices. *Journal of Housing Economics*, 56:101838.

Appendix

Figure 12: Instrument relevance (with clustered errors)



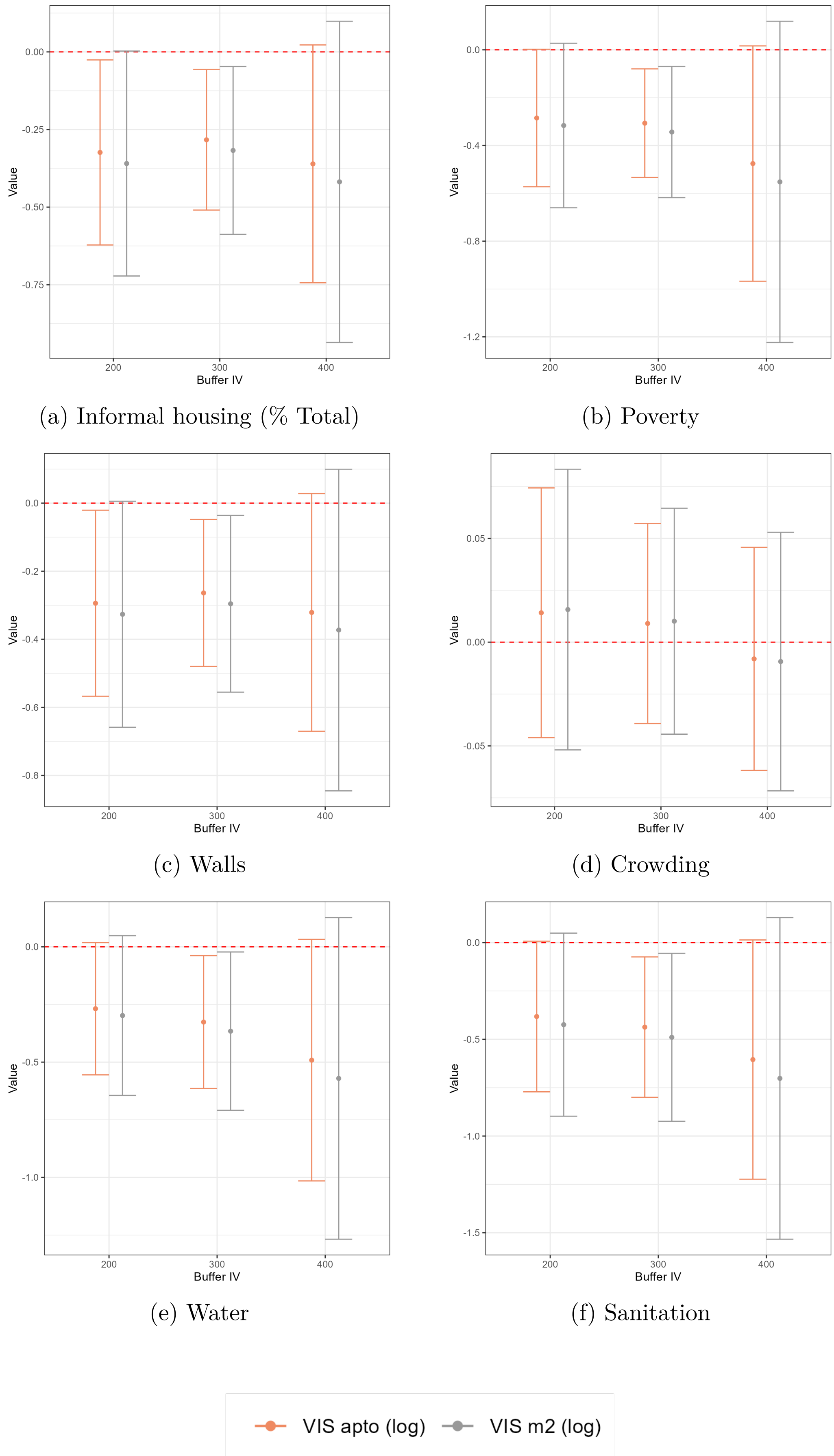
(a) Census track (Cluster)



(b) Grid (Cluster)

Source: Author's calculations. POT, 2014, Camacol, 2020; Census, 2018.

Figure 13: Estimation results (Census blocks and clustered errors)



(a) Informal housing (% Total)

(b) Poverty

(c) Walls

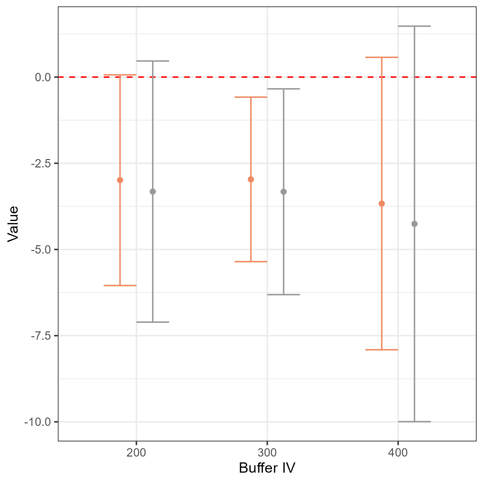
(d) Crowding

(e) Water

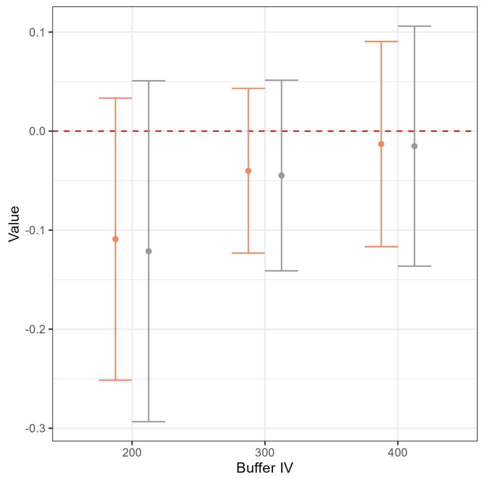
(f) Sanitation

Source: Author's calculations. POT, 2014, Camacho, 2020; Census, 2018.

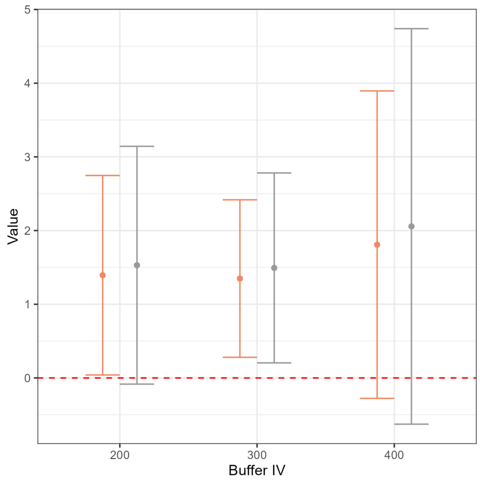
Figure 13: Estimation results (Census track and clustered errors)



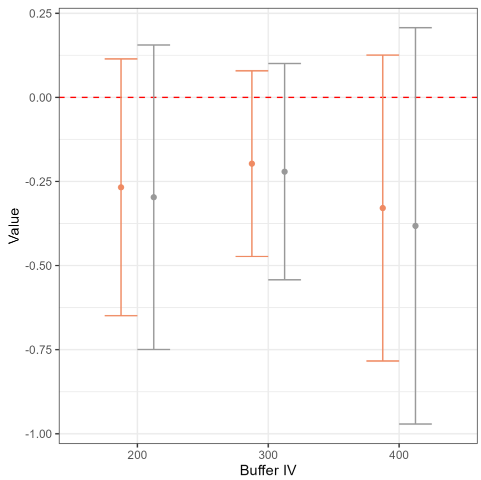
(g) Thefts (1000 hab.)



(h) Unemployment



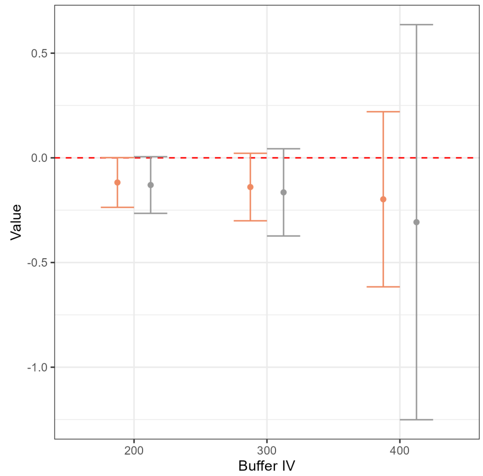
(i) Land value(log)



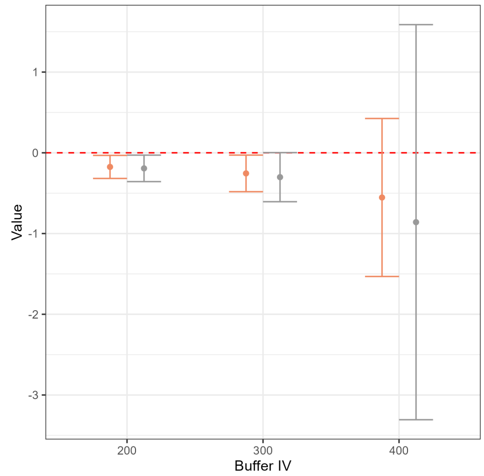
(j) Migration

Source: Author's calculations. POT, 2014, Camacol, 2020; Census, 2018.

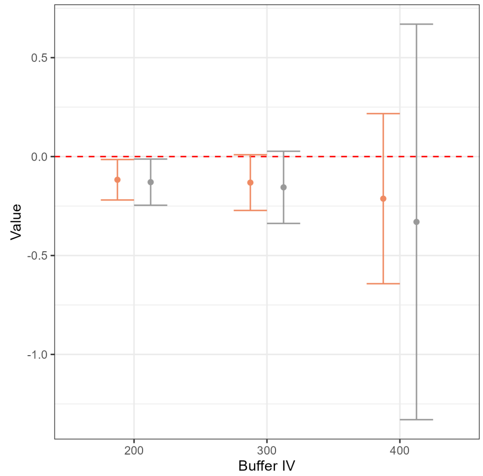
Figure 14: Estimation results (Grid and clustered errors)



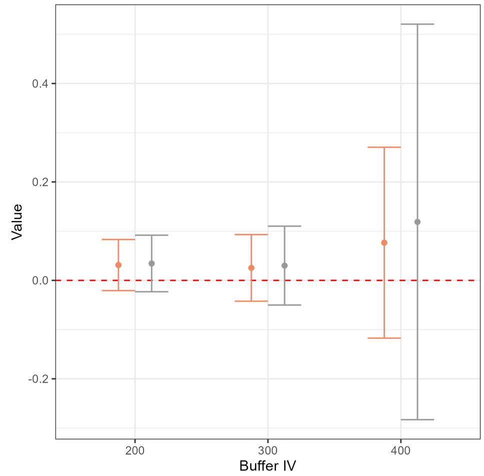
(a) Informal housing (% Total)



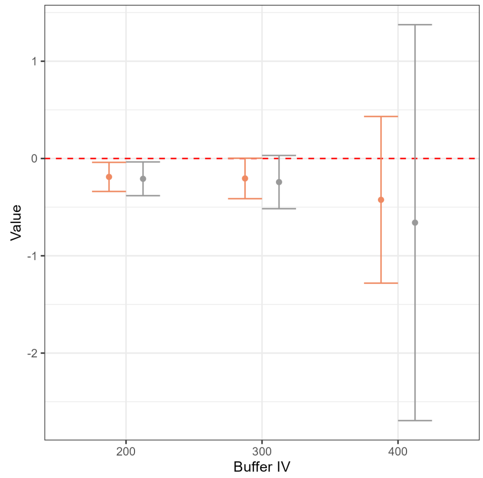
(b) Poverty



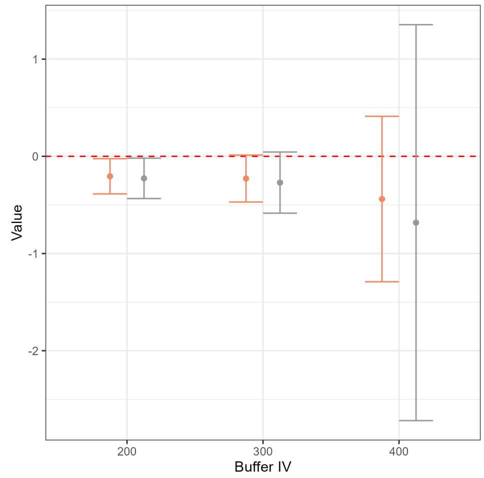
(c) Walls



(d) Crowding



(e) Water

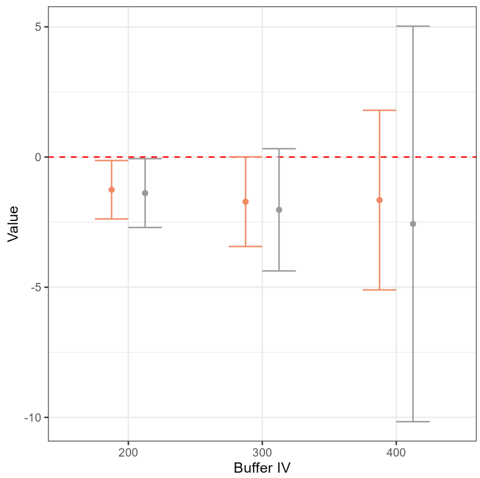


(f) Sanitation

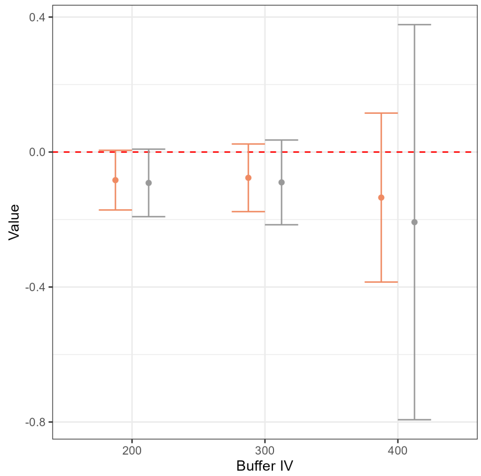
VIS apto (log) VIS m2 (log)

Source: Author's calculations. POT, 2014, Camacho, 2020; Census, 2018.

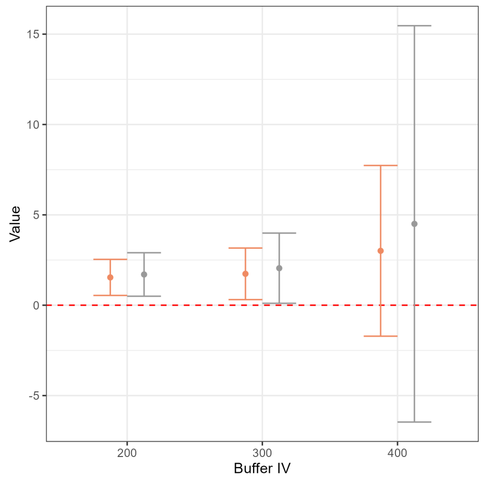
Figure 14: Estimation results (Grid and clustered errors)



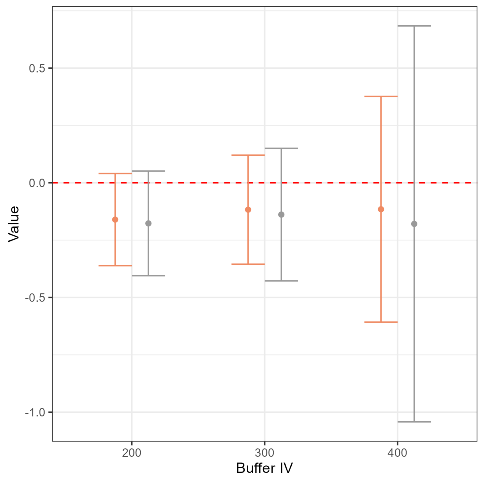
(g) Thefts (1000 hab.)



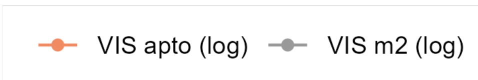
(h) Unemployment



(i) Land value(log)



(j) Migration



Source: Author's calculations. POT, 2014, Camacol, 2020; Census, 2018.

Tabla 1: First stage results

	VIS m2 (log)			VIS Apts. (log)		
	(1)	(2)	(3)	(4)	(5)	(6)
Unsuitable (200m)	−0.082***			−0.091***		
	(0.021)			(0.021)		
Unsuitable (300m)		−0.104***			−0.117***	
		(0.020)			(0.020)	
Unsuitable (400m)			−0.073***			−0.085***
			(0.020)			(0.020)
Constant	2.017***	2.071***	2.055***	2.077***	2.138***	2.124***
	(0.196)	(0.196)	(0.195)	(0.195)	(0.195)	(0.193)
Observations	4.619	4.619	4.619	4.619	4.619	4.619
Adjusted R^2	0.101	0.103	0.100	0.105	0.109	0.106
F Statistic (df = 13; 4605)	40.711***	42.009***	40.640***	42.823***	44.503***	42.923***
Note:						*p<0.1; **p<0.05; ***p<0.01

Tabla 2: VIS effect

	Informal housing (% Total)					
	Buffer IV					
	200	300	400	200	300	400
VIS m2 (log)	−0.360***	−0.317***	−0.419***			
	(0.111)	(0.079)	(0.127)			
VIS Apts. (log)				−0.324***	−0.283***	−0.361***
				(0.095)	(0.067)	(0.099)
Constant	0.956***	0.873***	1.071***	0.903***	0.821***	0.977***
	(0.234)	(0.176)	(0.272)	(0.206)	(0.156)	(0.222)
WI stat	19.765	34.964	18.933	24.363	43.948	25.523
WI p-value	0.000	0.000	0.000	0.000	0.000	0.000
Wu-Hausman stat	32.654	44.349	43.266	32.379	43.896	42.747
Wu-Hausman p-value	0.000	0.000	0.000	0.000	0.000	0.000
Observations	4.619	4.619	4.619	4.619	4.619	4.619
Note:						*p<0.1; **p<0.05; ***p<0.01

Geometric operations

Various geometric operations were performed to summarize the spatial information in the observational units of interest to construct some of the variables used in this exercise. In particular, the variables on the state of the road, the slope of the geography, and the value of the square meter are not built initially at the block level. First, a spatial intersection was made to identify which part of each original geometry corresponded to which block or grid. The area of these intersections was calculated, and finally, the variable's value was weighted by the percentage of the block area that belonged to it. Household variables such as poverty and vulnerability are built at the block level from the source, so we only apply the same process to obtain the measure at the grid level. It is important to clarify that the spatial intersection assumes that the attributes of the original geometry are spatially constant. Hence, the intercepted geometries inherit the same values as the original geometries.