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CAF DEVELOPMENT BANK OF LATIN AMERICA

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ABSTRACT

This paper investigates the impact of urban fiscal policies on housing value. We use a focalization system in Bogotá where certain subsidies and taxes are targeted based on a classification of houses according to external conditions and urban surroundings (socioeconomic stratification). We use a regression discontinuity design, and a rich dataset on cadastre appraisal and housing characteristics, to assess whether a higher tax burden affects the property value. Our results suggest that the usual (negative) capitalization effect is compensated by other channels. We show evidence that as stratum increases, investment on the house maintenance improve.

WORKING PAPERS

EL EFECTO DE LA ESTRATIFICACIÓN SOCIO-ECONÓMICA SOBRE EL VALOR DE LA VIVIENDA EN BOGOTÁ

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CAF - Documento de trabajo N° 2016/19
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RESUMEN

Este artículo investiga cómo el diseño de políticas fiscales urbanas afecta el valor de la vivienda. Estudiamos el caso de la ciudad de Bogotá, donde la tarifa de diversos impuestos y subsidios varía de acuerdo a un sistema de focalización que agrupa las viviendas según sus condiciones exteriores y su entorno urbano (estratificación socioeconómica). Usamos un diseño de regresión discontinua, y una completa base datos de avalúos catastrales y características de las viviendas, para establecer cómo una mayor carga fiscal afecta el valor de la propiedad. Nuestros resultados sugieren que la capitalización del impuesto, que debería generar menores valores de la vivienda, se ve compensada por otros canales. Presentamos evidencia de que uno de estos es que los propietarios reaccionan a la clasificación en estratos altos con mayor inversión en conservación de la vivienda.

Effect of socio-economic stratification on house value in Bogotá*

Final Report

Juan Gallego[†] Sergio Montoya[‡] Carlos Sepúlveda[§]

December 24, 2016

1 Introduction

Capitalization of fiscal policies on housing prices is a central question in urban and public economics. Taxes affecting housing markets can distort different household decisions, through channels (and magnitude of impact) depending on the structure and scope of these policies. Housing prices can be altered, for instance, by decisions to invest on the house (property materials); or household mobility to run away (or look for) taxes (or subsidies); or neighborhood spillover effects (public goods provision and habitat investment); or efficiency on the provision of specific public goods. Such channels emerge from the taxes design and their scope, as they can be focused con housing income, property taxes, or transaction costs (Bergantino et al., 2013; Gould, 2008; BCE, 2003; Oates, 1969).

We use a unique focalization system in Colombia where subsidies and taxes on utilities are targeted based on dwelling external conditions and habitat surroundings. All houses are classified in six groups called stratums; the lower ones (1, 2 and 3) received subsidies on the utilities bill (at a decreasing rate) and the higher (5 and 6) are affected by a consumption tax (at an increasing rate). This stratification has also an impact on property taxes. From this classification and a rich data set on cadastre, dwelling quality, urban context and appraisal value, we study the aggregate impact of

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such tax policy on housing prices in Bogotá, and explore possible channels that might take into place.

The "socioeconomic stratification", targeting houses instead of families, might generate significant distortion on housing values. The potential buyer of a house with a high classification in the stratification scale would expect higher future expenditures in public utilities, and some portion of this future flow of contributions is expected to be subtracted from the selling or rental price, unless there is a completely inelastic supply. On the other hand, houses with lower strata are favored with subsidies on utility payments that could also be anticipated and capitalized, with a positive impact on their prices. Since every sequential increase in strata means a decrease in subsidies or an increase in contributions, the effect of the capitalization would be the reduction of values for every strata addition.

The traditional explanation ignores the possibility of second order effects. Builders, for instance, can shift up markets (Ihlanfeldt, 2007), increasing the quality of housing to target a population less interested in subsidies. If the price-elasticity of demand is higher for better quality houses, it would be easier to transfer the value of the contribution to the buyer (or renter). In this scenario, given the lower capitalization and the increase in quality, the housing value could actually rise.

From a different perspective, there could be negative incentives to quality differentiation among strata. Lower strata residents could prevent urban improvements to reduce the risk of reclassification. Since the size of the subsidy/contribution is linked to the consumption of public utility services, and its weigth on total expenditure decreases as stratum rises, the relevance of the subsidy for lower groups would be significant to generate (negative) spillover on the neighborhood.

We use a Regression Discontinuity Design (RDD) that exploits the threshold between two different strata with similar score on the continuous variable that ranks the characteristics of each house in a low and high stratum. Through a hedonic pricing model, we are able to find positive effects of taxes on housing prices, which would suggest that the usual (negative) capitalization effect is compensated by other channels. We show evidence that as stratum increases (higher taxes), investment on the house materials improve.

2 Conceptual Framework

This paper is related to the literature on tax capitalization of local government programs. The seminal work of Tiebout (1956) hypothesized that property taxes should be capitalized, i.e., that the houses' values should decline with higher tax rates. Analogously, bigger local spending should increase property values. Around the local provision of public education on the U.S., Oates (1969) and Rosen and Fullerton (1977) find partial or closer to complete capitalization of public spending on housing values. In same line, Bergantino et al. (2013) show evidence of parcial capitalization of efficiency improvement in the local government for Italy.

One empirical challenge is to disentangle the effect of tax capitalization from the impact of local services financed by those taxes. From a natural experiment in California, Rosen (1982) estimates direct and positive taxes capitalization effects of a tax cut on land values. Lang and Jian (2004) used a change in state level regulation in Massachusetts that limits the capacity of municipalities to raise property taxes. They found that the communities that could increase more rapidly his property tax rate also saw rapid increases in property values. However, they were not able to isolate the second order effect that the restrictions on property taxing has on expenditure and on other taxes.

Bai et al. (2014) uses counterfactual analysis to assess the impact of trial property taxes in Chongqing and Shanghai. They found that new taxes increased the growth in property prices in Chongqing, but decreased it in Shanghai. The later result is coherent with the capitalization hypothesis. The former is explained by the tax design: only high-end houses (single family's) were subject to taxes and a part of the property was excluded from the them. Therefore, people willing to buy high-end houses before the tax implementation could change their minds and buy at the low-end distribution to avoid the tax. In the same direction, they could look for a property smaller than the tax-except size. These changes in demand can decrease the growth at the high-end prices and rise it at the low end. If the second effect dominates, the overall effect is a faster overall growth of prices. Du and Zhang (2015) uses the same natural experiment with a different identification strategy. They found no significant impact on property prices in Shanghai, with a low proportion of taxable homes. In Chongqing the presence of a trial property tax reduced the growth in property prices.

Another empirical methodology that takes advantage of Tiebout framework is related with the implementation of hedonic price models (Bergantino et al., 2013). Ihlanfeldt (2007) studied the effect of land regulations on property prices. These regulations increase the cost of building, and are partially incorporated in housing prices. But, additionally, the house size in zones with heavier regulations is greater –Builders shift up the market. The explanation is that elasticity of demand decreases with house size, so the higher cost are more easy to transfer to the buyer.

A few efforts in Colombia try to explore the relationship between taxes and housing prices. Medina and Morales (2007) start with a similar question than ours for 2003 data, and found greater housing prices for subsidized strata compared with similar homes in unsubsidized ones, by an amount they considered almost full capitalization of the present value of future subsidies. However, their empirical approach does not take into account urban characteristics of Bogotá and the presence of micro-segregation (Aliaga and Alvarez, 2010), having a transition between different socioeconomic levels not smooth around the city. More recently, Casas (2014) studies the impact of subsidies for energy consumption on the demand for rental housing in Bogota in 2003 and found an effect on housing size demand, which is interpreted as a signal distortion that subsidies impose on the rental market.

3 Data and identification strategy

3.1 Data

The data comes from the Special Administrative Department of City Real State Appraisal in Bogotá (UAECD for its acronym in Spanish), the office in charge of real estate appraisal used for the land property tax, and the District Planning Department (SDP for its acronym in Spanish), in charge of stratification. The UAECD's dataset for 2012 contains the inputs to estimate property values, such as location, land use, size of the property, built area, and materials and condition of the facade, ceilings, floors, kitchen and bathroom, among others. They also provide estimations of land and structure values per square meter, with which the total appraisal value of the property is estimated. We include in our sample only the dwellings that are zoned by the city's land authority for residential use. Table 1 presents the mean land, structure and total appraisal values[1] per m2 for each strata. It is evident that higher strata are associated with higher property values, as expected.

Table 1: Mean land, building and appraisal value per m2 by strata

Stratum	Land	Structures	Appraisal
1	273	146	120
2	577	321	358
3	844	466	600
4	1,251	809	975
5	1,378	838	1,253
6	1,663	963	1,730
Total	1,075	575	751

Source: Own calculations, UAECD

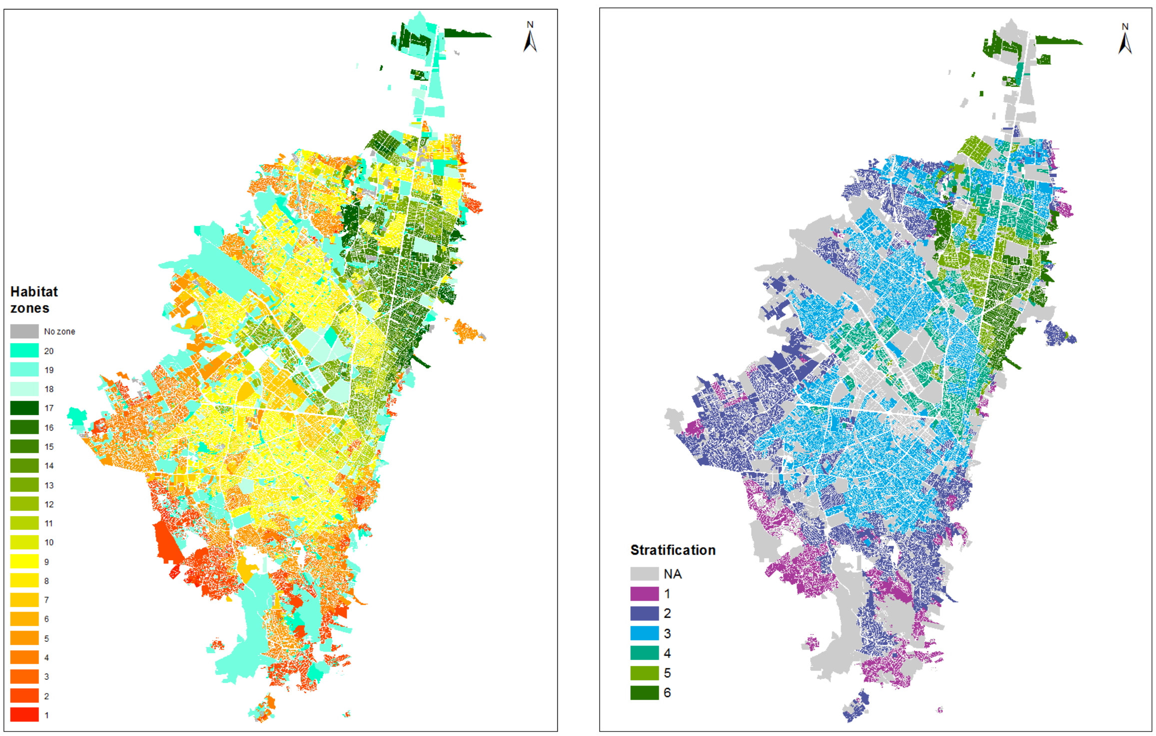
The dependent variables are the property values (land, structure and total), which determine the amount of the property tax, and are meant to resemble market prices. In the UAECD's method, first, a sample of different points in the city is selected. Then, expert appraisers are sent to assess the land and structures. Later, those assessments are matched with the information the UAECD have about houses' and neighborhoods' characteristics to run hedonic price models. Subsequently, the models fitted for this sample are applied to the whole universe of houses in Bogotá, in order to get predicted values (the total appraisal value is the sum of both land and structure). There is a drawback: the stratification itself is included in the prediction models. We run estimations with a different set of structure and total appraisal values, calculated by Gallego et al. (2014), with the same data and methodology as the UAECD, but excluding stratification as explicative variable in the appraisal model. Most of our results are qualitatively similar with or without this adjustment.

[1] Appraisal value per m2 is computed as total appraisal value of the property divided by the built area.

The second set of data is the one with which the SDP makes the strata assignment. It contains information about exterior physical characteristics of the houses in each side of each block with buildings in the city. Each block is classified in 'habitat zones', which are areas with homogeneous urban characteristics. The dataset is for 1997, when the current model of stratification was first applied, and 2009, where the strata classification in force in 2011 was issued. Figure 1 shows the spatial distribution of strata and habitat zones in Bogotá. There is a lot of concentration in both cases. Most of the blocks in the lowest strata are in the south and the west of the city, whilst more of the blocks in the highest strata are in the north-east of the city. The same applies to habitat zones (there is an ordering in the codification of habitat zones, being 1 the neighborhoods associated with poverty, and 17 the low-density residential zones; 18 to 20 are blocks with green areas, institutional buildings or unbuilt, see table A3)

Figure 1: Stratification and 'habitat zones' in Bogotá

(a) Spatial distribution of 'Habitat zones' (b) Stratification in Bogotá – 2015



3.2 Identification strategy

Stratification and assignment method

The stratification model applied in Bogotá assumes that the quality of housing is a good proxy for household's permanent income. Because of considerations of ease in data collection, at a time when it was necessary to quickly make a census of the entire city to generate the new stratification, the characteristics of the houses' physical exterior and their surroundings were the only two sources of information taken as input for strata allocation. The following section outlines the methodology designed by the National Planning Department (DNP) and adjusted for Bogotá.

The process begins with the collection of data for exterior physical characteristics. This was done for the entire city in 1997, and there has been partial actualizations since then in 1999, 2002, 2004, 2007, 2009 and 2013. The collection is made by officials of the SDP, for each block side[2]. Given their capacity to discriminate the quality of neighborhoods in terms of their income, a form with 8 variables was filled in for 1997. These are categorical variables describing sizes of the sidewalks, facade material, and presence of front gardens, among others. Then, a continuous index of exterior quality is constructed for each block, using a transformation into Savage scores[3].

The second step in the stratification methodology is the construction of 'habitat zones', a classification of blocks into groups with homogeneous urban characteristics. Two blocks belonging to the same type of habitat zone do not have to be close spatially; they can be in opposite parts of the city, but should have similar urban characteristics. These zones were defined by a formal body of the SDP (The Stratification Committee), based on the criteria presented in Table 1a. 20 types of areas were identified, of which 17 have residential uses. The distribution across the city is depicted in figure 1a. This zoning has a natural ordering, as shown in table 2: the areas listed first are expected to have lower income households , and those at the end of the list are expected to be more affluent.

The information from the exterior quality index and 'habitat zones' classification, both at block level, is combined to generate a classification in strata using a Dalenius-Hodges bivariate method[4]. Zone-specific optimal cutoff points in the external quality index are found in order to generate the 6 groups of the socio-economic stratification.

We will exploit the existence of these cutoffs points to control for unobservable

[2]A block is defined as a set of houses delimited roads.

[3]Lets $z^k_{i,l}$ be the k^{th} categorical indicative variable of exterior quality of the house, $k = 1, .., 7$, for side l of the block i. We define $\bar{z}^k_i$ as the average of the sides.

The savage scores for each variable are defined as:

$$h^k_i = \left(\sum_{j=N-r_i+1}^{N} \frac{1}{j} \right) - 1$$

Where h^k_i is the savage score for variable k in the block i, N is the number of blocks with residential buildings in the city, and r_i is the rank of i in the ascending ordered sample according to $\bar{z}^k_i$. The total value of the exterior quality index is obtained adding h^k_i for all the 7 variables.

Given a distribution of the Z's, there is only one value of the savage score associated

[4]Given a continuous variable, the Dalenius-Hodges methodology finds optimal cutoff points, so that the groups that are generated are heterogeneous with each other but have the minimum variance within. The methodology adopted for stratification in Bogotá was slightly modified to allow a bivariate setting.

variables when estimating the effect of stratification on housing prices. Two houses may have very similar values in the exterior quality index, but lie on different sides of the cutting point (at arbitrarily short distances). Each house will be classified in different strata, with impact on subsidies and taxation[5]. Imagine two houses with similar surroundings, with the same zoning ('consolidate residential', for example), but one was classified in stratum 3 and the other in 4. The first will receive a subsidy in the tariff for public utilities, while second will pay the cost-recovery price. Additionally, stratification in Bogotá functions as a signal of quality of housing and neighborhood. These two situations generate opposite effects on the demand for each house, with an unclear result for prices. However, the jump in the stratum assignment allows us to use a regression discontinuity design (RDD) to identify the total effect. In this environment, the treatment would be being in a higher stratum compared to the stratum immediately below, and the running variable would be the exterior quality index.

Empirical model

The main challenge for the identification of the impact of socio-economic stratification on housing prices is unobserved heterogeneity. On the one hand, a family with high income is expected to buy or rent a house with characteristics that simultaneously generates a high price and a high stratum, so we will observe a positive correlation between stratification and housing prices. Some of these characteristics of the house are easily observed, like the exterior features of the houses in the block (from the stratification census) or the construction characteristics of the house (from the cadaster database). But some other characteristics are not equally easy to observe, especially those related to the interior of the house or subjective assessments of the quality of the neighborhood.

On the other hand, the stratification is a focalization mechanism of many public programs. Among others, families living in a house classified in strata 1, 2 or 3 can access to subsidies on public services payments; one living in stratum 4 pays the cost-recovery price; and one living in strata 5 or 6 pays an additional contribution to finance the subsidies of the lower strata. Given that this flow of subsidies or contributions can be anticipated by the seller and the buyer (since the stratification of a house rarely changes), or the lessee and the lessor, this would likely affect the market prices.

We are interested in the possible distorting effect of attaching the focalization mechanism to the house, instead of attaching it to the household. But we need a way to control for the unobserved heterogeneity affecting the prices. As described in the previous section, the allocation mechanism for stratification suggests the possibility of applying a regression discontinuity design (RDD). The assignment mechanism uses a continuous variable, the exterior quality index, which determines the allocation of strata by the

[5]Table A4 presents the percentage of the full tariff that is paid by each household in each stratum with respect to the neutral stratum (stratum 4) in the different utilities (water/sewerage, gas and energy). The table discriminates by fixed tariff and variable tariff. The strata-specific tariffs for property tax are presented in table A5

definition of intervals –specific to each habitat zone– corresponding to each stratum. The cutoff points defining these intervals come to be a discontinuity in the allocation: around them there will be houses that obtained a similar score, but were classified in different strata. Our identification strategy will be a hedonic prices model with regression discontinuity design. The scale of 6 strata generates 5 discontinuities that can be analyzed.

For each block in the city we observe its classification in one of the 17 types of habitat zones, z, and the values of the exterior quality index, h_z. The discontinuities will be defined for each pair of consecutive strata $l \in \{(1,2),(2,3),(3,4),(3,5),(5,6)\}$ and each type of habitat zone z. In this way we would be comparing the price of homes with similar external physical characteristics belonging to urban areas with the same characteristics.

For each strata pair l we can define the treatment variable as:

$$D_{l,i} = \begin{cases} 1 & \text{si } h_i \geq \bar{h}_{l,z} \\ 0 & \text{si } h_i < \bar{h}_{l,z} \end{cases}$$

Where $D_{l,i}$ is equal to 1 if the house i exceeds the threshold $\bar{h}_{l,z}$ required to be ranked in the upper stratum within the pair l in the habitat zone z, and 0 otherwise (e.g. for the pair (3,4), $D_{l,i} = 1$ if the house is stratum 4 and $D_{l,i} = 0$ if the house is in stratum 3).

Our reduced form for the house value, specific to each pair l, will be:

$$V_i = \alpha + X_i\beta + f(h_i) + d_i^z\lambda + D_{l,i}\phi + \epsilon_i \qquad (1)$$

$$\text{For all } i \text{ such that } |h_i - \bar{h}_{l,z}| \leq \varepsilon$$

Where V_i is the housing value; X_i is a vector of house characteristics; $F()$ is a polynomial of order n of the running variable h_i; d_i^z is a set of fixed effects by habitat zone; ε is a bandwidth that ensures that houses in both side of the threshold are comparable; and ϕ is our parameter of interest, which captures the distorting effect of stratification.

Identification rests on two assumptions:

- Subsidies, signaling and segregation effects change discontinuously in the cutoffs, which is granted by the design of the allocation mechanism.
- The characteristics of housing, and households living in them, do not jump in the cutoffs. That is, for sufficiently close intervals around the cutoffs, it is possible to assume that the houses are similar and comparable.

Discontinuity in strata assignment

To avoid manipulation of the strata assignment, both by the households or by the local authorities, the values of the exterior quality index, the exact formula to aggregate the

7 exterior quality variables into the index and the intervals defining each stratum in each zone (and therefore the cutoff points) are not posted nor recorded, and not even observed by the SDP, the public office in charge of stratification. The officials in SDP enter the raw data (exterior quality variables and zonification) in an encrypted software that only reports the final strata assignment by block. Therefore, we had to recover the formula by replicating the methodology used in 1997 (savage score transformation) with the data they used to calibrate the formula (the database of Bogotá's decree 009 of 1997). We used the actual final strata assignment to locate the cutoffs. With the aggregation formula and the cutoffs recovered in this way we were able to replicate the 1997 stratification in 99.91% of the cases.

Since 1997 there has been six actualization to the strata classification in Bogotá[6], made with the purpose of taking into account the changes in the predominant features of some blocks and include neighborhoods recently developed. We observe land prices in 2011, so we should use the stratification in force in that time, corresponding to the actualization made in 2009. We can only observe the value of the exterior quality index in 1997, but most blocks haven't been part of any of the actualization so far. In fact, 60% of the blocks in the 2009 dataset haven't been affected by any actualization. This is the sample we will be able to use in our estimation.

Table 2: Strata by 'habitat zone'

Zone	Stratum						
	1	**2**	**3**	**4**	**5**	**6**	Total
1	173	0	0	0	0	0	173
2	3,783	52	0	0	0	0	3,835
3	0	29	0	0	0	0	29
4	0	3,864	0	0	0	0	3,864
5	0	7,249	0	0	0	0	7,249
6	0	144	0	0	0	0	144
7	0	28	117	0	0	0	145
8	0	264	2,961	0	0	0	3,225
9	0	7	6,467	0	0	0	6,474
10	0	11	694	0	0	0	705
11	0	0	233	0	0	0	233
12	0	0	14	425	0	0	439
13	0	0	8	1,449	0	0	1,457
14	0	0	0	0	37	0	37
15	0	0	0	103	751	0	854
16	0	0	0	0	46	557	603
17	0	0	1	2	11	108	122
Total	3,956	11,648	10,495	1,979	845	665	29,588

The strata assignment is the result of both the exterior quality index and the 'habitat

[6]In 1999, 2002, 2004, 2007, 2009 and 2013.

zone' classification, and the later is the most influential variable of the two. As shown in table 2, being classified in certain habitat zones almost determines the final strata allocation. For instance, all blocks in zone 1 are classified in stratum 1, and all block in zone 14 are classified in stratum 5 (see table A3 in the apedix for the descriptions of the zones). This also implies that we will have observations near the cutoff point for specific combinations of strata changes and zones. In particular:

- For the change form stratum 1 to 2, we only will observe properties in zone 2, associated with poverty.
- For the change from stratum 2 to 3 we will observe properties in zones 7, 8, 9 and 10, associated with industrial areas and neighborhood of consolidated progressive development.
- For the change from stratum 3 to 4 we will observe properties in zones 12 and 13, associated with intermediate residential neighborhoods.
- For the changes from stratum 4 to 5 and 5 to 6, we will observe only properties in zones 15 and 17, which are exclusive residential or low-density residential zones.

Although the methodology adopted for stratification in Bogotá allowed for multiple threshold points for each strata transition, depending on the habitat zone, in practice the thresholds coincide within each strata transition[7]. This will allow us to avoid transformations in the running variable for the RDD. There is, however, an additional issue with the discontinuities: the density surrounding the threshold for the strata transitions 1 to 2 is not enough to make a appropriate estimation.

4 Results

4.1 Basic results

Table 3 presents the RD estimates of the effect of an stratum increase on housing valuations. With six groups in the stratification in Bogotá, we analyze five strata transitions. Since the boundary between strata is determined by specific conditions in terms of external quality index and membership of certain habitat zones, we have no prior reason to assume that the effect is homogeneous between different strata. Additionally, each stratum is different in terms of the magnitude of the subsidy/contribution assigned, and an upward reclassification would imply different increases in the fare paid for public utilities. The income of the families living in different strata is also different, so the subsidy/contribution would affect differentially the housing demand. Because of these considerations, we present estimation separately for four counterfactual strata transitions. The first strata transition, from 1 to 2, was excluded from the analysis because there was not enough observations to carry on the analysis.

[7]This is not a coincidence, but a consequence of the discrete nature of the Dalenius-Hodges methodology an its adaptation for stratification in Bogotá

Figure 2: Location of blocks used for RDD

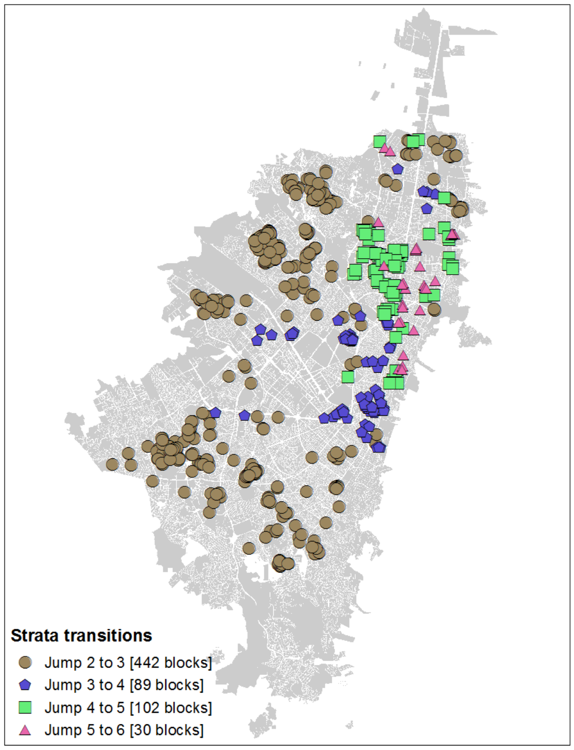


Table 3: RDD estimates on housing values

	Appraisal	Land	Structure	Observations
Jump 2 to 3	0.170***	0.191***	0.148***	(Left=3252)
	(0.035)	(0.059)	(0.033)	(Right=8575)
Jump 3 to 4	0.176**	0.678***	0.363***	(Left=1432)
	(0.075)	(0.194)	(0.119)	(Right=3514)
Jump 4 to 5	0.256***	0.240*	0.331***	(Left=4139)
	(0.069)	(0.138)	(0.072)	(Right=2475)
Jump 5 to 6	-0.031	-0.170	0.098	(Left=1199)
	(0.065)	(0.212)	(0.107)	(Right=964)

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.
Jumtp 2 to 3: Cutoff is -2.155. Optimal bandwidth is 0.601.Blocks to the left of the BW: 99. Blocks to the right of the BW: 343.
Jumtp 3 to 4: Cutoff is 3.019. Optimal bandwidth is 1.295.Blocks to the left of the BW: 14. Blocks to the right of the BW: 75.
Jumtp 4 to 5: Cutoff is 8.216. Optimal bandwidth is 0.646.Blocks to the left of the BW: 42. Blocks to the right of the BW: 60.
Jumtp 5 to 6: Cutoff is 15.210. Optimal bandwidth is 0.528.Blocks to the left of the BW: 15. Blocks to the right of the BW: 15.

We find significant and positives effects of an upward strata reclassification. The first row of table 3 shows that a house in stratum 3 would cost 17% more per square meter of building than a similar one in stratum 2. This effect can be decomposed in a 19% increase in land value, and a 15% increase in structures value. For the jump from stratum 3 to 4 we observe similar increases in the appraisal value; a house in stratum 4 would cost 18% more per square meter of construction, the structures would cost 36% more, and the land would cost almost 68% more. An upward reclassification of a property in stratum 4 would increase the property value per built square meter in about 26% and the structures value in 33%; the land value per square meter would increase in 24%, but only statistic significant at 10 %. In the transition from stratum 5 to stratum 6 we found a decrease in value, the results are somehow negative, but no significantly different from zero, which means that a reclassification to stratum 6 would neither increase or decrease the housing value.

Comparing the changes in along the strata, we can see some important effects. Both lowering subsidies and having (or) increasing contributions have positive final effect on housing values. This shows the significant impact of indirect effects of taxes. The effect in lower stratums (2 to 3) is smaller than other transitions (i.e. 3 to 4 or 4 to 5). The potential explanation for this effect is based in the fact that the monetary value of subsidies on water, sewage and energy represents around 7% in stratum 1 and 3.5% in stratum 2 from the family income. In this sense the direct (and negative) effects of taxes on house value should be higher impact for households in low socioeconomic strata. In addition, a direct (an negative) effect of increasing taxes might be important as well on higher stratums (5 to 6) since the aggregate change in prices is non-significant. As the taxes on electricity and on gas consumption are the same for both stratums, this result might be driven by house taxes or water sewage's contributions. In particular property taxes as percentage of family income are higher at stratum 6 than 5[8].

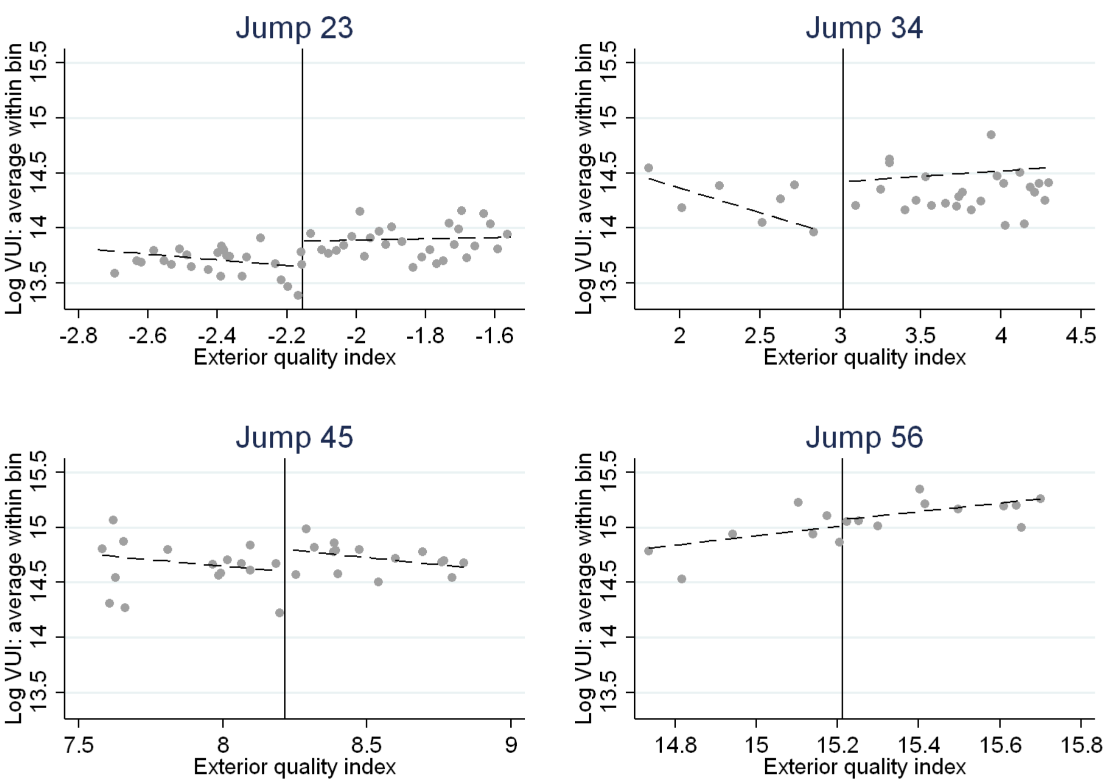
An additional result worth highlighting is the impact of a change from stratum 3 to 4. Relative to other possible transitions, moving upwards within these strata would have a quite significant increase in the land price (this is similar than the effect of the structure value along other changes). Stratum 3 is the last group receiving utilities subsidies, so we can think as transition from industrial areas with emerging but still disadvantage parts of the city to more residential ones. In general, the city is usually divided into two main groups (1, 2 and 3 as subsidized or "lower stratums" or 4, 5 and 6 as "higher stratums"). This division reflects an inequality in terms of both amenities and household income. The price of land reveals the conditions of the house surroundings (paving, security, mobility and other amenities), so either the signaling or the segregation channels might be taking place in this group (prices in structure reflect mainly house materials, so the investment theory most probably enters into play for this).

Figure 3 shows the mean property values –VUI– around the discontinuity threshold,

[8]Table A5 presents the average subsidy (contribution) and average taxes on property and the percentage of those values with respect to family income for the year 2011 in Bogotá.

within the optimal bandwidth[9]. A visual inspection reveals patterns similar to what is obtained in table 3: higher values to the right of the cutoff for strata transitions 2 to 3, 3 to 4 and 4 to 5, and no discernible difference for strata transition 5 to 6. This visual examination, however, do not take into account the controls used in the RDD regression, and this difference accounts for small discrepancies between the table and the figure (like strata transition 4 to 5 having the biggest impact in the regression, but not so clearly in the figure).

Figure 3: Discontinuity in property values.



Note: The figure only includes observations within the optimal bandwidth. Bins over the exterior quality index are calculated using the IMSE-optimal quantile-spaced method with polynomial regression. The fitting lines are calculated using linear local regressions with a triangular kernel.

[9]The graph divides the observations within the optimal bandwidth in bins calculated with the IMSE-optimal quantile-spaced method using polynomial regression, and presents the averages.

4.2 Mechanism linking stratification and housing values

Property tax/subside capitalization

A large body of literature has studied the capitalization in house prices of local public goods (like school or public spaces) and property taxes. One of the first theoretical finding was that the portion of the tax applicable to land would be absorbed by the land owner, in the form of lower land rents and therefore lower land prices (this is the capitalization of the tax). But the part of the tax applicable to structures would, in the long run, be transferred to the purchasers, because the tax would reduce the return on investments in construction, this would reduce the supply of structures in the future, and would generate higher prices Oates (1969).

The effect of a property tax depends on whether it is 'onerous', in the sense that there is not a local expenditure compensating the increased tributary burden, or 'remunerative', this is, if the tax is accompanied by benefits. In the former case, the house price is expected to decline. But in the later, property prices could actually rise. The taxes linked to stratification are likely to be classified as onerous, because the there is not a direct local benefit attached to the contribution, and as consequences the impact of higher strata should be expected negative on house value if capitalization is the only mechanism, however as results on table 3 shows other potential channels explainning those impacts.

Investment distortions

The expectation to receive subsidies / pay contributions associated with the classification of properties can change other decisions, besides prices. The Tiebout-Oates model predicts that the supply of structures could decrease in the long run in areas with higher property tax rates. Nevertheless, Aliaga and Alvarez (2010) maintain that stratification in Bogotá has augmented the residential density in higher strata[10].

One of the distortions that stratification generates on investment is that people would avoid to make housing improvements that would likely change their classification (because that would have a cost in terms of public utility payments or in terms of socioeconomic reputation). Even efforts by local public authorities, like the improvement of roads in recently settled neighborhoods, have been boycotted by the beneficiary community, to avoid upward strata reclassification[11]. People already in the next stratum have not this concern, so they have not incentives to refrain from investment. Therefore, two properties that were similar at the moment of the first stratification, but were assigned to different strata, would have different land ans structures value today, because of the post-stratification differences in housing investment.

[10]Data from Bogotá's Cadaster shows that blocks with lower stratum have fewer properties. In our sample, the average block in stratum 1 have 22 properties, in stratum 2 have 49, in stratum 3 have 151, in stratum 4 have 236, in stratum 5 have 169 and in stratum 6 have 141

[11]We would like to thank Denis López to bringing this to our attention

Subsidies and contribution can play an important role in this mechanism. If tenants can rent a place in stratum 3 with subsidies or a similar place in stratum 4 without them, then they would prefer the former option, unless there is a compensation for the lack of subsidy. It could be a lower price for properties in stratum 4, as in the capitalization mechanism, but it could be also an improvement in some feature of the house (like interior materials and conditions). In this scenario the owner, instead of reducing his asking price, would make additional investments to compensate for the lack of the subsidy.

The DAECD evaluates the conservation status of the kitchen, bathrooms, building finishes and structures, each with a scale of 1 to 4. For each property in our sample, we generated a aggregate index of conservation as the sum of these four individual items (so our scale if from 1 to 16). We use the same regression discontinuity design as before to assess the impact of stratification on the conservation status of the properties. Table 4 shows our results.

In absence of investment distortions, we would expect no effect of a hypothetical upward reclassification on conservation status; in other words, the owner of a house in a higher stratum would have no reason to make a greater effort to maintain his property. Data suggest the opposite, higher stratum is associated with better conservation status, which is evidence of a systematic increase in maintenance efforts by owners of properties in higher classifications.

Table 4: Differences in conservation across strata

Jump 2 to 3	0.544**
	(0.226)
Jump 3 to 4	3.480***
	(0.759)
Jump 4 to 5	1.011*
	(0.565)
Jump 5 to 6	2.147***
	(0.802)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Stratification and residential segregation

Several studies have found evidence of residential segregation in Bogotá (Aliaga and Alvarez, 2010; SDP-UN, 2011). Aliaga and Álvarez suggests that one of the causes of this segregation is the socio-economic stratification. On the one hand, it increases the density of the more affluent neighborhoods of the city. On the other hand, the division in strata is already assimilated in the culture. Moving to a neighborhood with a lower stratification is seen as downward social mobility, whilst moving to a neighborhood with a higher stratification is not necessarily seen as upward social mobility, and people belonging to the same stratum recognize themselves as member of the same socioeconomic group. A survey in Bogotá revealed that 58% of the residents of the city wouldn't move to a neighborhood with higher strata, should they turn rich (Uribe, 2008). This result could suggest a relation between stratification and taste for segregation.

Lets assume that people like to live in neighborhoods with similar levels of income or education. One way of imposing the separation of neighborhoods is through prices (valuations), so that certain neighborhoods are only accessible to families above certain income level. Local public goods can generate these kind of price differentials, but it is also dependent on the preferences of the families on the provision of said public good. On the other hand, it is possible that the price differential is motivated by a purely arbitrary feature of the neighborhood. Stratification could serve this purpose. Maybe the valuation of houses in higher strata is higher, not because they believe those houses to be better or that the neighborhood has more amenities, but because they know that those neighborhoods will have certain level of income, given the extra expenditure of the price differential caused by the stratification.

Stratification as signaling

Let's assume that potential buyers of real state have uncertainty about the quality of the houses that they can buy, but the sellers have certainty about its features. The buyers would search for any signals of the quality of the house, and they know that the local authorities make an evaluation of the exterior characteristics and urban context of each property, and classified them *publicly* in six groups. Therefore, stratification can be used as a signal of quality.

If stratification indeed functions as a signal of housing quality, we would expect this signal to be more informative in contexts with more uncertainty. We can use dispersion (variance) in house quality as a proxy for uncertainty. However, if the features measured by our proxy are observable, even an area with a lot of dispersion could have low uncertainty. Therefore, we would like to use a measure of house or neighborhood quality that is difficult to observe for the house buyers. The classification in habitat zones is a good option: it is the assessment of an expert, so the house buyer probably lacks the required information and skills to extract this information with accuracy.

Since habitat zones are a qualitative classification of the blocks of the city, more than a quantitative proxy, we will use the inverse of the Herfindahl–Hirschman index as a measure of dispersion [12]. A neighborhood with high concentration (i.e. a low value in the inverse HH index), is one in which most of the houses belong to the same habitat zone; we would say that this neighborhood is homogeneous according to our metric, so there should be low uncertainty. On the other hand, in a neighborhood with low concentration (i.e. high value in the inverse HH index) the houses are evenly distributed among several habitat zones; there is heterogeneity in our metric of quality.

If the houses in strata 2 and 3, for instance, have a huge dispersion in quality, there could be a source of uncertainty that motivate buyers to read stratification as a

[12] $Inverse\ HH\ index = (\sum_i p_i)^{-1}$, where p_i is the proportion of properties in the sample belonging to habitat zone i.

Table 5: Zone habitat concentration and RDD effects

	Inv. HH			Ratio			
	Both	Low	High	$\frac{IHH_l}{IHH}$	$\frac{IHH_h}{IHH}$	Diff.	RDD
Jump 2-3	3.70	2.08	1.92	0.56	0.52	0.04	0.170
Jump 3-4	3.13	1.92	1.69	0.62	0.54	0.07	0.176
Jump 4-5	2.50	1.69	1.23	0.68	0.49	0.18	0.256
Jump 5-6	2.22	1.23	1.14	0.56	0.51	0.04	-0.031

signal. However, the dispersion *within* strata also affect the usefulness of the signaling mechanism. If the dispersion within strata is the same as the total dispersion, then the signal is not informative. Therefore, we should look at the ratio of the within strata dispersion to the total dispersion. As it goes to 1 the signal is less informative, and as it goes to 0 the signal is more informative.

Table 5 shows the calculations of the inverse HH indexes for each stata jump in our sample, and within each strata (for the lower and the higher strata of each dyad). The ratio of the within strata dispersion to the total dispersion in that strata jump is also reported. The last column shows the estimated effect of belonging to a higher strata, as seen previously in table 3. We would expect more informative signals to be associated with higher impacts on land prices. However, either a higher or a lower stratum could be an informative signal, and they have opposite impacts in land prices. So, the comparison of our measure of informativeness and our RDD estimations is not straightforward. However, the difference among the lower and the higher strata in our measure of informativeness, do have an straightforward interpretation. If the higher strata is more informative than the lower strata, we should expect higher housing values for these houses with an informative signal of good quality. This is what we can observe in the table: the strata increase in which the higher strata has the biggest informativeness advantage is the one with the biggest impact on housing prices.

4.3 Validity of the RDD

Sensibility analysis

The optimal bandwidths for all the former estimations have been computed using the MSE-optimal criterion (Imbens and Kalyanaraman, 2011). Even so, to show that the previous results are not dependent on the bandwidth choice, we have run the same regressions, expanding and contracting the size of the bandwidth. Table 6 presents the results for a bandwidth 120% and 80% the size of the original. For the jumps from stratum 2 to 3 and from 5 to 6, the change in the bandwidth do not generate important changes in the estimates, and the significances are preserved. For the jump from stratum 4 to 5, the result for total appraisal is stable; the significance of the effect on the structure value is preserved, but there are important variations in magnitudes (however, they fall inside the 95% confidence interval of the original estimation); for land, nevertheless, the significance is lost, but the change in magnitudes is not large. Finally, for the jump from strata 3 to strata 4, we found that an increase in the size of the bandwidth preserves the results, but a decrease in the size generate incoherent estimations. This is a consequence of the number of observations in the bandwidth, which do not allow for reductions without relying in a excessively small sample.

Table 6: Sensitivity analysis on Bandwidth size

	Jump 2 to 3		
	Appraisal	Land	Structure
With pptimal BW	0.170***	0.191***	0.148***
	(0.035)	(0.059)	(0.033)
With 120% optimal BW	0.171***	0.214***	0.126***
	(0.028)	(0.048)	(0.028)
With 80% optimal BW	0.182***	0.203***	0.154***
	(0.038)	(0.064)	(0.036)
	Jump 3 to 4		
	Appraisal	Land	Structure
With pptimal BW	0.176**	0.678***	0.363***
	(0.075)	(0.194)	(0.119)
With 120% optimal BW	0.203***	0.757***	0.394***
	(0.061)	(0.197)	(0.108)
With 80% optimal BW	-0.140	-0.367	-0.345
	(0.155)	(0.434)	(0.281)
	Jump 4 to 5		
	Appraisal	Land	Structure
With pptimal BW	0.256***	0.240*	0.331***
	(0.069)	(0.138)	(0.072)
With 120% optimal BW	0.235***	0.165	0.270***
	(0.062)	(0.136)	(0.068)
With 80% optimal BW	0.233**	0.276	0.370***
	(0.091)	(0.171)	(0.097)
	Jump 5 to 6		
	Appraisal	Land	Structure
With pptimal BW	-0.031	-0.170	0.098
	(0.065)	(0.212)	(0.107)
With 120% optimal BW	-0.027	-0.154	0.083
	(0.067)	(0.203)	(0.104)
With 80% optimal BW	-0.043	-0.192	0.140
	(0.068)	(0.233)	(0.110)

Placebo test

We did a placebo test estimating the jump in land, structures and property values at non-discontinuity points. Ideally, we would like to run a placebo for each side of the cutoff value. However, our sample do not have enough density of values in the regions below the thresholds (see figure 4), so we can only use the subsamples of observations above it. Following Imbens and Lemieux (2008), we test for jumps at the median values of the subsample. We found no jumps in any of the housing value variables for any of the subsamples (7).

Figure 4: Distribution of external quality index

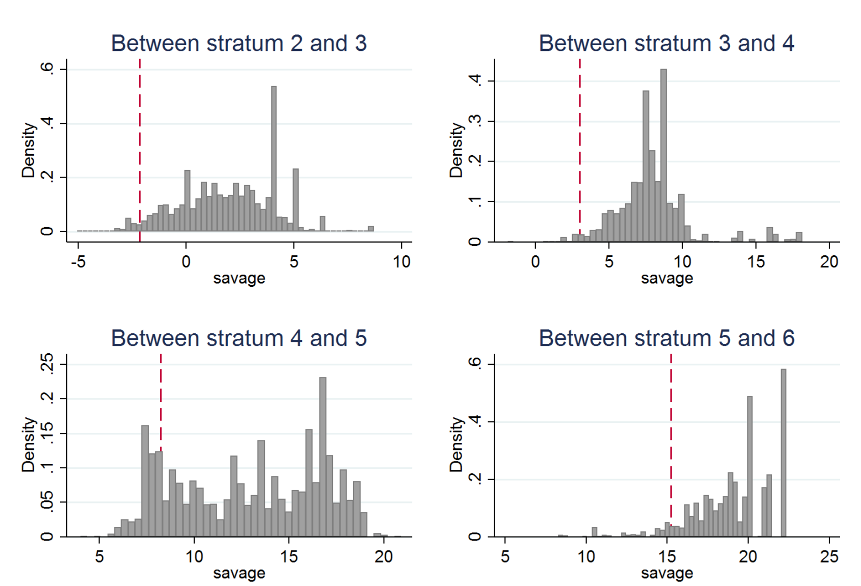


Table 7: Placebo test, with artificial cutoff points

		Appraisal	Land	Structure	Observations
Jump 2 to 3	Above	0.023	0.021	0.022	(Left=24085)
		(0.021)	(0.036)	(0.018)	(Right=29254)
Jump 3 to 4	Above	-0.011	0.015	-0.002	(Left=34507)
		(0.027)	(0.046)	(0.029)	(Right=38100)
Jump 4 to 5	Above	0.012	0.027	-0.031	(Left=1722)
		(0.048)	(0.089)	(0.037)	(Right=1947)
Jump 5 to 6	Above	0.068	-0.049	0.068	(Left=1435)
		(0.087)	(0.124)	(0.081)	(Right=9503)

Treatment manipulation

The manipulation of the strata assignment mechanism by house-owners is unlikely. On the one hand, our sample only includes houses which classification did not change between 1997, when the stratum for every house in the city was re-assigned, and 2011, when we observe house values. Therefore,there has not been reclassifications in our sample that reflects the ability of the house-owners to manipulate the system. And before 1997, the methodology for strata allocation was different; at the time of the urban census that collected the information used for the classification, people didn't know what information was going to be collected and how it was going to be processed.

On the other hand, the strata assignment methodology is still not entirely transparent for house-owners. The variables used in the methodology are widely known, and each house-owner can consult in the SDP how his property was evaluated and in which habitat zone was classified. But the exact values used in the transformation from the 7 categorical variables of exterior quality to the continuous index (using the savage score method) are not known, even for the officials in charge of the stratification in the city. The cutoff points, obtained using the bivariate Dalenius-Hodges method, are also unknown[13]. Hence, house-owners have difficulties identifying whether their property's score is close to the threshold, or the physical changes on propoerty that can affect their score.

Additionally, changes in a single property are not likely to change stratification. The information about exterior qualities of the houses is captured at block side level; the official making the appraisal should identify which are the *predominant* features of that side of the block. Once this information have been collected at block side level, it is aggregated at block level with a simple mean. So, if the residents of a block in the city want to change the exterior characteristics of their properties to cause a reclassification, they first have to solve a coordination problem. In our sample, each block has on average 35 houses, so coordination wouldn't be trivial.

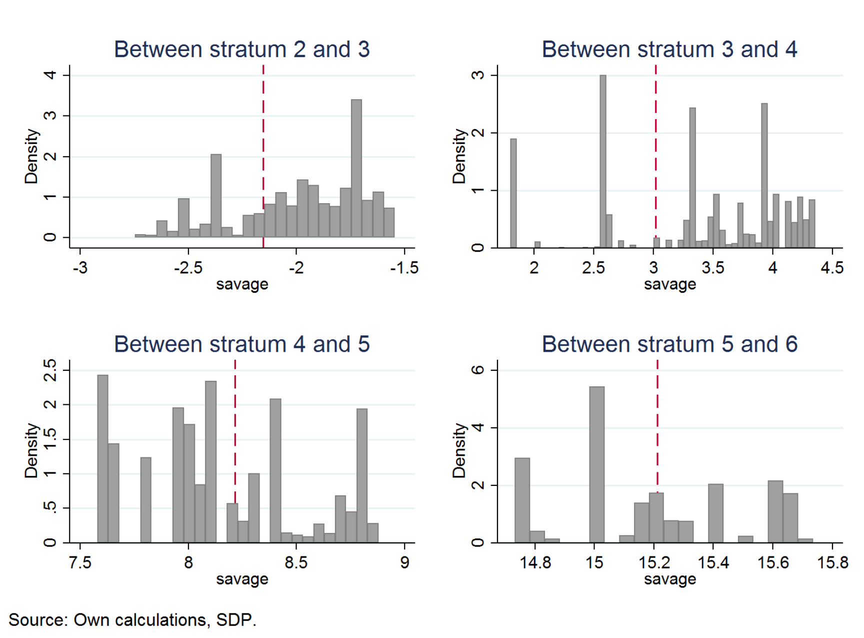
The usual way to test for manipulation is through a discontinuity test for the density of the running variable (the exterior quality index in our case) at the discontinuity point (McCrary, 2008). The discontinuity in the density, if it exist, would be a signal of manipulation. However, the strata assignment method in Bogotá generates jumps in the density of the exterior quality index not caused by manipulation.

5 Conclusions

This study uses a housing classification system in Colombia (social stratification) design to focalize subsidies and taxes on public services (utilities), and analyses its possible aggregate (direct and indirect) consequences on housing prices. Through a hedonic price model, we use a regression discontinuity design (RDD) to take advantage of a

[13]The officials at Bogotá's SDP introduce the collected information about the 7 categorical variables and the habitat classification in a software that calculates the continuous index, the cutoffs and the corresponding stratification. The only output of the software is the strata classification.

Figure 5: Distribution of external quality index within the optimal bandwidth



discontinuity change in stratums (6 stratums based on houses exterior quality materials) over a continued quality index and compare, on average, prices of nearly equal houses allocated in two different stratums. The main direct effect explores by the literature is the property tax/subsidy capitalization which predicts a negative (positive) impact of taxes (subsidies) on housing prices; but important indirect effect might arise (investment distortions in housing or public goods, segregation, or signaling of urban context or house quality), all of which predict positive effect of taxes on prices.

Taking a rich data set on housing for Bogotá (property value, quality material and habitat surroundings) we find that on aggregate, there are positive effects of an upward strata classification on the prices of housing, suggesting the important roll of indirect effects, especially in the transition of intermediate stratums. The evidence suggests that one indirect mechanism that is taking into place is the improvement of the housing quality to compensate the fall of prices given the taxes. Further analysis need to be made to explore the possibility of signaling or segregation because the stratification mechanisms.

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Appendix

Table A1: Descriptive statistics

	Mean	SD	Min	Max	Obs
Appraisal value m2 (log)	14.06	0.58	11.75	15.73	751,636
Building value m2 (log)	13.56	0.76	9.39	15.58	751,636
Land value m2 (log)	13.25	0.60	8.35	15.36	751,636
Built area	132.61	112.14	1.10	19862.95	751,636
Land area	80.77	135.44	0.33	68544.12	751,636
Cadastre score	46.00	16.48	0.00	98.00	751,636
Year of construction	1986	13	1910	2011	751,636
Co-ownership	0.45	0.50	0	1	751,636
Exterior quality index	3.68	6.47	-5.61	22.36	751,636
Habitat type 7	0.00	0.04	0	1	751,636
Habitat type 8	0.13	0.33	0	1	751,636
Habitat type 9	0.29	0.45	0	1	751,636
Habitat type 10	0.01	0.10	0	1	751,636
Habitat type 12	0.03	0.17	0	1	751,636
Habitat type 13	0.12	0.32	0	1	751,636
Habitat type 15	0.07	0.25	0	1	751,636
Habitat type 16	0.06	0.25	0	1	751,636
Habitat type 17	0.00	0.07	0	1	751,636

Source: Own calculations, SDP, DAECD.

Table A2: OLS estimates

	Habitat zones in sample			
	Appraisal	Land	Structures	Observations
Jump 2 to 3	0.110***	0.190***	0.051***	318,510
	(0.013)	(0.022)	(0.016)	
Jump 3 to 4	0.138**	0.804***	0.143	119,308
	(0.066)	(0.207)	(0.098)	
Jump 4 to 5	0.084***	0.016	0.102***	50,422
	(0.028)	(0.053)	(0.032)	
Jump 5 to 6	0.293***	0.497***	0.269***	52,274
	(0.041)	(0.084)	(0.051)	
	All habitat zones			
	Appraisal	Land	Structures	Observations
Jump 2 to 3	0.098***	0.202***	0.022	538,546
	(0.014)	(0.022)	(0.015)	
Jump 3 to 4	0.129**	0.742***	0.206	439,204
	(0.057)	(0.189)	(0.140)	
Jump 4 to 5	0.054**	0.107**	0.099***	163,866
	(0.025)	(0.045)	(0.028)	
Jump 5 to 6	0.175***	0.304***	0.185***	95,139
	(0.038)	(0.081)	(0.047)	

Table A3: Number of stratified blocks by 'habitat zone' in 2009

Criteria	Zone	Zone description	# Blocks	Proportion
1	1	Poverty (-)	387	1.0%
	2	Poverty (+)	6,607	17.3%
2	3	Tolerance zone	67	0.2%
3	4	Unconsolidated progressive development (-)	5,004	13.1%
	5	Unconsolidated progressive development (+)	9,733	25.4%
4	6	Urban decay	152	0.4%
5	7	Industrial	168	0.4%
6	8	Consolidated progressive development (-)	3,901	10.2%
	9	Consolidated progressive development (+)	7,037	18.4%
7	10	Predominant commercial (-)	748	2.0%
	11	Predominant commercial (+)	262	0.7%
8	12	Residential intermediate (-)	605	1.6%
	13	Residential intermediate (+)	1,621	4.2%
9	14	Commercial compatible	52	0.1%
10	15	Exclusive residential (-)	1,000	2.6%
	16	Exclusive residential (+)	656	1.7%
11	17	Low-density residential	295	0.8%
12	18	Institutional	-	-
	19	Lot without houses	-	-
	20	Green area	-	-
		Total	38,295	100.0%

Source: SDP

Table A4: Structure of tariffs in domestic public services

		Water/Sewerage	
Stratum	Fixed tarif	Variable Tarif (<20M3)	Variable Tarif (>20M3)
1	30%	30%	100%
2	60%	60%	100%
3	86%	86%	100%
4	100%	100%	100%
5	249%	151%	151%
6	346%	161%	161%
		Energy	
		Variable Tarif (<130Kwh)	Variable Tarif (>130Kwh)
1	-	42%	100%
2	-	52%	100%
3	-	85%	100%
4	-	100%	100%
5	-	120%	120%
6	-	120%	120%
		Gas	
		Variable Tarif (<20M3)	Variable Tarif (>20M3)
1	0%	50%	100%
2	0%	63%	100%
3	100%	100%	100%
4	100%	100%	100%
5	120%	120%	120%
6	120%	120%	120%

Source: Own calculations

Table A5: Public utility services and contributions, and property tax

		Average subsidy or contribution by services				Tax property	Average income
Stratum		Water/Sewerage	Energy	Gas	All		
1	2011 ($)	$ 37,724	$ 23,059	$ 9,225	$ 70,008	$ 1,610	$ 1,057,081
	% of Income	3.6%	2.2%	0.9%	6.6%	0.2%	
2	2012 ($)	$ 20,959	$ 19,105	$ 6,829	$ 46,893	$ 3,387	$ 1,345,689
	% of Income	1.6%	1.4%	0.5%	3.5%	0.3%	
3	2013 ($)	$ 7,583	$ 5,906	$ -	$ 13,488	$ 13,557	$ 2,290,080
	% of Income	0.3%	0.3%	0.0%	0.6%	0.6%	
4	2014 ($)	$ -	$ -	$ -		$ 38,183	$ 5,026,124
	% of Income	0.0%	0.0%	0.0%	0.0%	0.8%	
5	2015 ($)	$ (47,177)	$ (13,159)	$ (6,901)	$ (67,238)	$ 85,397	$ 6,501,345
	% of Income	0.7%	0.2%	0.1%	1.0%	1.3%	
6	2016 ($)	$ (64,189)	$ (17,252)	$ (5,571)	$ (87,012)	$ 124,973	$ 8,510,986
	% of Income	0.8%	0.2%	0.1%	1.0%	1.5%	
Total	2017 ($)	10823.38	10344.86	2921.102	24089.35	16128.46	2413764
Bogotá	% of Income	0.4%	0.4%	0.1%	1.0%	0.7%	