Stratification and Public Utility Services in Colombia: Subsidies to Households or Distortions on Housing Prices?[•]

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Abstract

In Colombia there is a cross subsidy system which charges subsidized rates to the households who live in low-income neighborhoods, and taxed rates to households that reside in high-income neighborhoods.

This document assesses the hypothesis that the flow of subsidies that potentially comes from a particular house, may be discounted by housing market agents so that most of them are transferred to the prices of the houses that receive the subsidies.

In order to estimate the effect that subsidies to domiciliary public utility services can have on housing value, the prices for houses on both sides of the boundaries of different socioeconomic strata are compared, that is, houses subject to different public utility service rates, and it is found that the increment in house value explained by differences in the subsidies received by households, is similar in magnitude to the present value of the flow of subsidies discounted at reasonable market rates. Likely effects of these subsidies are found on the rent amount.

Although the results found include information only for Bogotá, we think the same would be consistent with the current situation in the main Colombian cities. The above takes us to conclude that the functions of financing subsidies for the poor population through public spending in domiciliary public utility services in Colombia is being achieved, if anything, in a very limited way. Most of the fiscal effort on this subject has as its final effect, the distortion of housing prices in different socioeconomic strata. While the system assigns 0.7% of GDP each year in supposed gross subsidies to domiciliary public utility services in Colombia, the only thing they end up doing is introducing an additional characteristic into a set of households that they would not have without government interventions, and moving the housing market to auctioning such characteristics, with the consequent distortion on houses relative prices.

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1. Introduction

There is ample consensus about the convenience of subsidizing the consumption of public utility services, due to the positive externalities derived by their supply, and the high public costs generated by their absence. Based on these principles, most Latin-American countries subsidize their supply, and constantly try to improve their targeting systems and to minimize social losses associated with the subsidy schemes.

States in the region that allocate subsidies to domiciliary public utility services, DPS, (for its acronym in Spanish), have always found a matter of controversy and discussion in the way subsidies should be targeted to population, with subsidies coverage and targeting systems often criticized from the beginning.[1] Among the ways used in the region to reach households with these DPS subsidies, we find cross subsidy schemes, subsidies to supplying utilities, cash transfers, etc. Such variety of alternatives, along with the socioeconomic and cultural diversity of the countries of the region, have caused that the regional consensus about the relevance of handing out subsidies, does not exist on the way they should be targeted.

To the lack of technical consensus, it can be added the difficulty to reform the targeting systems derived from the complex political economy of subsidies in the region, even more when some governments which have been installed in the area, have sought their consolidation through subsidy policies to the poor population.

A great deal of Colombian policy regarding social and equality matters through public spending has been channeled by means of guaranteeing access to public utility services to the needy population. Actually, the targeting strategy used to provide those subsidies has

[1] The Colombian case is a clear example. Among recent studies which have assessed Colombia's current system, and that have formulated proposals to improve it, are Fernández (2006), Meléndez (2004) and INECON (2006). The Colombian government has also taken some steps towards a system reform with proposals such as the one in DNP (2005).

become part of the population poverty and welfare measurement methodologies as one of the determining criteria.[2]

The country has several studies which have quantified the DPS public expenditure amounts, and the way these are distributed among households of different income levels. However, there are no studies that quantify how much of this expenditure actually goes in the form of subsidy into the pockets of the households of the housing units in which subsidies become effective, rather than ending up being transferred or distorting other factors such as relative housing prices. This document presents a quantification of the incidence the DPS subsidies and contributions have on housing prices, based on which, it estimates the net subsidy the government transfers, and actually stays, in households pockets.

Therefore, starting from the concerns that can be found in previous studies, we test the hypothesis that subsidies or contributions play a role in determining housing prices, to identify some of the limitations of the current targeting system of subsidies to public utility services. In order to quantify the incidence of DPS subsidies on house prices, hedonic price equations are estimated, in which we apply a regression discontinuity approach as our identification strategy. The empirical work is done with information from Bogotá, however, the institutional mainframe that rules the DPS subsidy targeting policy is the same countrywide, so we expect our results will be consistent with the situation found in Colombia's main cities.

It is found that the estimated increment in house value because of subsidies is similar in magnitude to the present value of the flow of subsidies, discounted at reasonable market rates. Comparable effects are found when we assess the effect of subsidies on leasing prices.

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[2] In particular, the System of Beneficiaries Selection (SISBEN), a proxy-means test used to order households from poorest to richest, uses the stratum of the household in order to compute the index. The index is used to target more than 2% of GDP annually in health supply and demand subsidies.

This takes us to conclude that the function of subsidy financing for the poor population through public utility services fiscal spending in Colombia, is not being achieved. Most of the fiscal effort on this matter would have as its final effect, the distortion on housing prices in different socioeconomic strata. While the public sector distributes approximately 0.7% of the GNP in allegedly subsidies to public utility services in Colombia each year, its final effect is to introduce an additional characteristic to a set of houses, that would not have it without such expenditure, and moving the housing market to auction such characteristic, with the consequential distortion on housing relative prices.

The article begins presenting the subject's background for Colombia, in which the way the country has consolidated its targeting strategy, and the targeting principles, are described. Then, we summarize the findings of related studies, describe our methodology and data, and the results of empirical exercises. Finally, we present the conclusions.

2. Background

The targeting mechanisms implemented by the Colombian government since the second half of the *XX* century has changed very slowly, from simple ones based exclusively on consumption levels, to more complex ones that combine both consumption levels and characteristics of housings and their neighborhoods. Until 1968, the country delivered subsidies to public utility services by means of a scheme of increasing block pricing, IBP, with very low rates for the lower levels of consumption, and higher rates as consumption levels increased. This strategy, lacked a strong legal mainframe for its application, a reference unitary cost of services provided for the allocation of subsidies, and was supported on direct government financing of the required infrastructure developments. Even though it was inspired under the principle by which those better off would have higher consumption levels, and thus, would be subject to higher rates; rich and poor households showing a below average consumption benefited from a subsidy amount and ended up paying a rate below the cost of providing the service, a reason why utility companies did not have favorable cost recovery levels and were not able to undertake infrastructure investment, network maintenance and others, which inevitably caused a detriment in quality of the services supplied and a low coverage expansion. This scheme ended up characterized by high levels of inclusion of non poor and exclusion of the poor. In addition, its unfavorable fiscal balance led it to be considered as a generalized subsidy scheme.[3]

In order to improve the targeting of subsidies, by 1968, the *Junta Nacional de Tarifas*, JNT, the Colombian institution in charge of determining public utility services rates and monitoring utilities compliance with rates, introduced two new inputs to the targeting mechanisms: (i) the definition of a basic consumption level, which would have the higher subsidized rates, and (ii) different IBP structures conditional on housing appraisal.[4] By 1984, the JNT substituted the use of the housing appraisal method with the Department of National Statistics socioeconomic strata system, which characterized housing units according to their characteristics and those of their neighborhoods. Still, under this new scheme the system recovered only up to a 39% of electricity cost of supply.[5] Once this change took place, users publicly complained by means of manifestations, providing an example of how sensible this issue is in the country.

Seeking to improve the stratification as targeting mechanism, the JNT, along with other utilities, developed new stratification methodologies between 1984 and 1989.[6] Nonetheless, by then utility companies, which were mostly public, kept having poor cost recovery levels, low infrastructure investment, poor quality and limited coverage expansion.[7]

With the new legal guidelines from the beginning (1991 Constitution) and middle of the nineties (laws 142 and 143 of 1994), a new conception of domiciliary public utilities took shape in Colombia, which focused on the implementation of an efficient supply of public

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[3] See INECON (2006) y Millán (2006).
[4] Ibid.
[5] See Millán (2006).
[6] Ibid.
[7] Even though the first companies born in Colombia aiming to supply public utility services grew between 1875 and 1930 and were out of private initiative, after that period; they were bought by the State, which by 1970 had become the main public utility services supplier in the country. See Meléndez (2004).

utility services based on the criteria of solidarity, self-financing, redistribution, and of course, social and economic efficiency.[8]

The government assigned the task of designing the methodology for municipalities to stratify to the Department of National Planning, DNP, while municipalities were responsible to implement it at least every five years. There would be six socioeconomic strata, being strata one to three subsidized, the fourth would pay the marginal cost of the services, and strata five and six, along with the commercial and industrial sectors would pay contributions. Subsidies would be granted only to consumption levels below the basic.[9] Since socioeconomic strata were created, they have been used as well to set differentiable rates such as taxation and university tuition fees, to grant access to health subsidies, etc.

Latin American experience with subsidies to public utility services: the case of piped water

Subsidies to public utility services are a common characteristic in most Latin American countries. As it is shown by ADERASA (2005), in the case of piped water and sewerage, more than 10 countries in the region, except Chile, have demand cross subsidies, some have direct subsidies, and most have investment subsidies.[10] Most importantly for our purposes: most countries have geographically based targeting mechanisms, thus, the inferences we will get in this article are likely to apply for several of them.[11]

3. Literature Review

Previous studies aiming to estimate the incidence of residential subsidies to public utility services in Colombia have adopted an accounting approach by which they estimate the amount of subsidies generated in each housing unit, and then proceed to sort households by income in order to estimate how subsidies are assigned across the income distribution.

[8] See DNP (2005).
[9] Basic consumption levels were fixed in 200 KWh/month, and 20 M^3/month.
[10] Among the countries with cross subsidies to piped water and sewerage they report Argentina, Bolivia, Brazil, Colombia, Costa Rica, Nicaragua, Panama, Paraguay, Peru, and Uruguay.
[11] Among the countries geographic targeting mechanisms to assign piped water and sewerage subsidies they report Argentina, Bolivia, Brazil (Sao Paulo), Colombia, Panama, and Peru. In addition, Paraguay and some cities from Brazil use household characteristics and socioeconomic conditions.

Table 1 presents the distribution of demand subsidies in Bogotá to piped water and electricity for 1970, 1992 and 2003.[12] From the table emerges a clear pattern: increases in the subsidies between 1970 and 1992, and reductions between 1992 and 2003, in particular, for electricity. Such reduction might have had to do with the changes introduced by the 1991 Constitution along with laws 142 and 143 of 1994, which promoted a self sustainable system of provision of public utility services. On the other hand, even though it can be observed that the incidence of subsidies relative to earnings is higher for the poorest, the distribution of subsidies across deciles has been historically somewhat progressive, but in a very modest magnitude.

Table 1. Subsidy as a percentage of household's income. Bogotá.

Decile	Piped Water				Electricity		
	1970*	1973**	1992	2003	1970*	1992	2003
1	NA		3.0	7.6	0.2	5.7	5.0
2	NA		1.7	3.4	0.4	3.6	2.2
3	NA	2.1	1.3	2.5	0.3	2.6	1.7
4	0.9		1.1	1.9	0.3	2.3	1.2
5	0.7	1.2	0.8	1.5	0.3	1.7	1.0
6	0.5		0.6	1.1	0.2	1.5	0.7
7	0.4	0.3	0.5	0.7	0.2	1.3	0.5
8	0.2		0.3	0.4	0.0	0.9	0.3
9	-0.2	-0.6	0.1	0.2	-0.1	0.7	0.1
10	-0.8		0.1	-0.1	-0.1	0.3	-0.1
Total			0.47	0.48		1.19	0.31

NA: Not Avalilable. 1992: Vélez (1996), 2003: authors' estimates based on ECV2003.
* Source: Gutiérrez de Gómez (1975), quoted by Selowsky (1979).
** Source: Lundquist (1973), quoted by Selowsky (1979).

Other studies have evaluated and proposed targeting alternatives to stratification. Among these studies we find Selowsky (1979), Vélez (1996), Sánchez and Núñez (2000), Meléndez (2004), Fernández (2004), Lasso (2004), Montenegro and Rivas (2005), and INECON (2006), among others.[13] Meléndez proposes to lower the basic or subsistence consumption levels for water and electricity (conditioning on altitude in the case of

[12] Sánchez and Núñez (2000), Meléndez (2004), Fernández (2004), Lasso (2004), and INECON (2006) do not report estimates for Bogotá.
[13] Even the government did it in a recent policy document (see DNP (2005))

electricity), and complementing stratification with the use of additional housing characteristics and the level of education of the head of household in order to determine whether the household is eligible for subsidies, should pay the marginal cost or should pay a contribution.[14] Fernández (2004), assessed the accuracy of stratification in targeting the poor, and estimated that for all public utility services the inclusion error increased from 53% to 58% between 1993 and 2003, making evident the limitations of the system.[15] INECON recognizes as well important deficiencies in the targeting mechanism based merely on stratification, mostly due to the wide heterogeneity of households residing in stratum three. It mentions the potential use of a Colombian proxy-means test denominated Sisben as a better option than stratification; nonetheless, it points out several drawbacks previously detected in that instrument that would require it to be improved with respect to its current standards. Finally, it estimates the magnitude of gross demand subsidies to be 0.67% of GDP, with contributions of 0.41% of GDP, to get a net demand subsidy of 0.26% of GDP.[16] In addition, the system receives nearly 0.3% of GDP in supply subsidies.

Finally, DNP (2005), analyses the nature and convenience of socioeconomic stratification as targeting instrument. The policy document highlights several limitations of the stratification as a targeting mechanism, and recommends assessing it and redesigning its methodology. In addition, it requests the evaluation of new conditions for households living in stratum three to become beneficiaries of subsidies, such as Colombian's proxy-means test, denominated Sisben.

As mentioned earlier, previous work on the topic does not deal with the issue of whether the estimated amount of subsidies received by each housing unit is ultimately benefiting the

[14] In July 2004, the Colombian government mandated the gradual reduction in electricity basic consumption levels from 200 KWh in 2003, to 173 and 130 KWh in municipalities below and above an altitude of 1000 meters respectively, by 2007 (See INECON (2006)).
[15] Inclusion error in this paper, is understood as the fraction of the population receiving subsidies whose income is not among the first two fifths of the income distribution.
[16] It includes gross subsidies to households in strata 1, 2 and 3, to piped water (0.15%), sewerage (0.08%), telecommunications (0.09%), and electricity (0.32%). The magnitude of demand subsidies estimated is consistent with Lasso (2004), who found a gross subsidy of 0.73% of GDP and contributions from strata 5 and 6 of 0.2% of GDP. About 0.2% of the contributions come from commerce and industry, the other 0.2% of GDP comes from households in strata 5 and 6.

household that inhabits it, the landlord if different from the tenant, or none of these but just distorting relative housing prices.

4. Methodology

Even if demand subsidies to DPS can affect the value of multiple factors associated to them, and also have bearings on the behavior of household members, this paper focuses on the incidence these subsidies can have on housing prices, and therefore, on estimating the subsidy households receive, net of such effect.

Our approach is based on the hypothesis that the housing market takes into account the flow of subsidies or taxes that residents of certain dwellings will receive or pay. To clarify this concept, let's suppose two identical houses are compared, one in stratum 4 and the other one in stratum 3, and that in addition, they are located on the same street, one in front of the other. In this hypothetical case, the only difference between the houses would be their stratum, and the subsidy level that the one located in stratum 3 would have compared with the one in stratum 4, which would pay the total cost of the service. If the monthly subsidy received by the inhabitants occupying the house located in stratum 3 is S_i, then these residents would be willing to pay the net present value of the flow of subsidies expected to be received, net of their deadweight loss. This is the standard tax capitalization approach, developed by Oates (1969).

To find the DPS subsidy incidence on housing prices, a hedonic price function is estimated. The estimated function describes the equilibrium that reveals the willingness to pay by heterogeneous market agents for each one of the characteristics that comprise the non-elastic housing supply.[17] The relationship we estimate is the following:

$$\ln(p_{ij}) = \alpha + X'_{ij}\beta + \gamma S_{ij} + u_{ij} \qquad (1)$$

Where p_i is the price of house i located at strata j, the X_{ij} vector contains characteristics of the house and its neighborhood (at the census sector level), S_{ij} is the monthly DPS subsidy

[17] The estimated Coefficients of that function represent the price paid by the marginal purchaser. See Rosen (1974)

amount that could potentially be obtained by living in the house, and u_{ij} is a random shock.[18] According to our previous argument, if the capitalization approach works, then we would expect a positive effect of subsidies on housing prices in equation (1).

Specifications similar to the one defined in equation (1) have previously been estimated for Colombia and other countries.[19] Nonetheless, the precision of the results depends on whether one includes all relevant information associated to housing prices. As it can be observed in figure 1, there is significant variation in subsidy amounts within each socioeconomic stratum, which could be explained by the heterogeneity in DPS demand within stratum, as a function of characteristics of dwellings and those of their inhabitants. In addition, we will exploit subsidy variations explained by the different DPS IBP faced by housings on both sides of strata borderlines.

If the changes in subsidies to DPS consumption are mainly associated with changes in household socioeconomic stratum, then it is important to control for the characteristics that determine the stratum for each house, the ones that are only partially observable. In addition, the characteristics that determine the stratum for a set of houses, can change in different zones of the same stratum, and be associated with the houses appraisal in different ways. For example, a set of houses could be in stratum six because of their luxurious

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[18] Variables such as number of bathrooms and bedrooms, quality of piped water and sewer services, the presence of services in the home, etc. are included, and from neighborhoods, variables such as the proximity to green zones, transportation terminals or airports, etc. There is a group of important variables that have as their source the District Real State Appraisal such as the built area and the lot area and some strata dummy variables interactions with the built area and lot that are introduced to capture the differentiated effect of the dimensions of the units across the different strata. S_i is calculated based on the paid amount in every DPS reported by the households in the Living Standard Measurement Survey of 2003, the socioeconomic strata based on which the energy bill is charged, and with the rate structure for each one of the services in Bogotá for June 2003, which are published in the sites of control entities in Colombia: http://www.creg.gov.co/ (Comisión Reguladora de Energía y Gas)(Electricity and Piped Gas Regulatory Commission), http://www.cra.gov.co/ (Comisión Reguladora de Agua)(Piped Water Regulatory Commission), and http://www.superservicios.gov.co/ (Superintendencia de Servicios Públicos Domiciliarios)(Superintendence of Domiciliary Public Utility Services). The amounts of subsidy received by each household for electricity, piped gas and water and sewage are included. Besides the linear subsidies, their squares are as well included in the regression to allow detecting possible non-linearities on the effect of subsidies on housing prices.

[19] Among the papers that use this approach for Colombia are the Castellar (1991), which estimates the implicit price of different attributes of the peasant's farm, and the Carrianzo (1999), which performs hedonic regressions for Bogotá's housing market. Lasso (2005) estimates a similar equation in which he aims to determine the incidence of DPS subsidies on house rental value in Colombia. International literature on hedonic prices and their methodological approaches can be read in Castellar (1991), Cheshire and others (1999).

characteristics, while others could be in the same stratum because they have a better provision of public goods, even if they are not as luxurious. Omitting this information could potentially bias the results from equation (1).

To overcome these difficulties, our approach begins by taking advantage of the form in which the socioeconomic stratification is determined for housing units in urban areas in Colombia. In this process, each city is divided into six socioeconomic strata that somehow represent housing areas that share similar characteristics. Despite such stratification, it is important to note that the number of strata is small to cluster all houses of each city in homogeneous groups, so that differences in characteristics of houses of different strata become actually significant.

This aspect becomes clear when the case of Bogotá is analyzed. A city with over 40 thousand blocks of houses is grouped in six strata for the purpose of subsidy targeting, just as any other city in the country. In this case, each stratum contains an average of seven thousand blocks, Thus, it is hard to make the case that all housing units are significantly different across strata.

Under the mentioned stratification system, we would expect that houses on both sides of the borders that divide socioeconomic strata have more subtle differences the closer they are to their nearest boundaries. Thus, comparing houses close to the border on both sides will control for unobservable characteristics of houses and their neighborhoods. If, in addition, it is possible to differentiate neighboring houses in a sector of the city from those in another sector (say, stratum 2 in the center of the city versus stratum 2 in the south), it will also be possible to control for unobservable differences like the ones associated to the supply of public goods in different parts of the city. To account for these factors, the following model is estimated:

$$\ln(p_{ijb}) = \alpha + X'_{ijb}\beta + K'_{b}\delta + \gamma S_{ijb} + u_{ijb} \quad (2)$$

where K_b represents a vector of boundary dummies. These variables are such that every house close to a borderline between two strata is associated to only one boundary dummy, and all houses near that boundary will also be associated to the same boundary.

Empirically, it is not obvious whether the omitted variable problem, if present in our exercise, would underestimate or overestimate the results obtained from equation (1). On the one hand, the effect of introducing the boundary dummies, would depend on the correlation between them, net of the controls already included in (1), and the subsidies. On the other hand, comparing different sets of houses according to their distance to their respective boundaries, would correct potential biases as we take houses closer to their closest boundaries, coming mostly from comparing incomparable households, but in an unpredictable way.

Our methodology is thus based on the following assumptions: (i) subsidies change discontinuously at the boundaries, (ii) observable and unobservable characteristics of houses change continuously at the boundaries, (iii) the effect of public utility subsidies on house prices is continuous at the boundaries, and (iv) the amount of subsidies is independent of its effect on house prices at the boundaries, once controlling for the side of the boundary.[20]

Annexes 1 to 3 present evidence that differences in means of the characteristics of houses on opposite sides of their respective frontiers, becomes statistically not significant for several of the control variables, as we consider houses that are closer to their respective frontiers. While houses that are on average 750 m. from the frontier, 58% of the control variables have means that are statistically different on both sides of the frontiers, only 42% of them are different when considering houses 150 m. from their respective frontiers.

To provide further evidence, we split the sample into those households located on the better and worse sides of their respective boundaries, and compute local linear regression, LLR, estimates of all variables for each of these samples.[21] Annex 2 illustrates the results for

[20] Assumptions (i), (ii), (iii) and (iv) are know as the standard RD, the continuity of characteristics and treatment effect, and conditional independence assumptions.

[21] LLR is a nonparametric regression technique, in which estimates can be obtained by running weighted least squares of the variable of interest Y_i, for each house i with value of Prob(distance to nearest frontier = D_j), on a constant term, and on the difference Prob(distance to nearest frontier = D_j)-Prob(distance to nearest frontier = D_i), using data on other houses j on the same side of the boundary. The estimated intercept will be the LLR

energy and water subsidies, and for some control variables, including whether the kitchen is a individual room, the number of bathrooms, whether the dwellings are houses or not, and whether the house has potable water service. Although the control variables shown in the figure seem to register a discontinuity around the boundaries, annex 3 shows that none of them actually does. Annexes 1 to 3 present evidence that strongly supports assumptions (i) and (ii) enumerated above. First, they show how differences in LLR estimates of energy and water subsidies, evaluated near the boundaries, are statistically significant across boundaries. Secondly, they show that as we move closer to the boundaries, to a point right next to them, only 12.5% (instead of the 42% obtained 150 m. from the boundary in annex 1) of the control variables remain being statistically different across boundaries, providing additional evidence that as we move closer to the boundaries, differences across boundaries in housing units and their neighborhoods diminish.[22]

Errors in stratum measurement

The methodology used to identify the effects of DPS subsidies on housing prices requires the socioeconomic stratum of the house to be precisely measured, since the measurement of the subsidies received by the household, our variable of interest, crucially depends on this.

In the ECV2003, each household is asked what stratum does public utility services companies base the billing on for their electricity service. In principle, the stratum information should be taken directly from the electricity bill provided by a member of the household answering the survey. However, in some circumstances, the stratum written down by the interviewer could not match the household's actual electricity stratum, not to mention the piped water and sewerage stratum, which is not asked for in the survey and

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estimate $E(Y_i|Pr(D_j))$. We use a biweight kernel, $K(s) = 15/16\cdot(s^2-1)^2$ for $|s|<1$, $K(s) = 0$ otherwise, where $s = Pr(D_j) - Pr(D_i)$, as weights, and a half bandwidth (the magnitude that defines the distance from i which we are using to select the other houses j to get our estimate) of 300 m. (using other bandwidths we obtained similar results). LLR estimates are better than the more traditional kernel regression estimator because its bias does not depend on the density of the data, and the order of convergence of its bias is the same at boundary points as at interior points (see Fan 1992, 1993, and Heckman et.al. 1998).

[22] The difference in house valuation across boundaries is not statistically significant because it does not control for characteristics that differ across boundaries. Nonetheless, it becomes clear from annexes 1 and 3 that once we compare houses closer to the boundaries, the difference not only shortens, but also changes its sign in the expected way.

might be different than the one for electricity, even for the same house. In some cases, the electricity bill is not available at the time of the survey. In this case, the surveyed individual could report not knowing what the stratum is, and the interviewer will record it as unknown. The individual could also report an incorrect stratum.

Also, as foreseen by Dane (2003), in case that the electricity bills does not specify the stratum in some cities, but report the residential qualitative category ranging from "Low-Low" to "High", the interviewer translates those categories into strata.[23] It can also be the case that there is a small business or factory in the house and due to this, the electricity bill is paid at commercial or industrial rates. In this case, the interviewer has to assign the most frequent stratum reported in houses of the same housing segment the house is located in.

On the other hand, it can be the case that in condominiums or buildings, where the survey is answered by several households, one of the interviewed homes does not provide information about the electricity stratum and/or how many times per week the garbage truck comes by to pick up the trash. In this case, the interviewer deduces the stratum from other forms filled in that same condominium or building.[24]

As it was mentioned before, the stratum of housing units in our sample is based on ECV2003 data and also, on the information collected from the Administrative Department of District Real State Appraisal of Bogotá, DACD (for its acronym in Spanish). However, the stratum obtained from the DACD information could have a measurement error as well, since this data is available only for year 2000, three years before the ECV2003 was collected, and therefore, some households could have had their stratum changed before the survey.

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[23] The assimilation is done based on the following convention: Low–Low→stratum 1, Low→stratum 2, Middle–Low→stratum 3, Middle→stratum 4, Middle–High→stratum 5, and High→stratum 6.

[24] In addition, it is recommended to the surveyors to take into account that **in one same block** the stratum can change from one house to the other. However, the DAPD claims that the city stratification is defined for all the houses on the same block, and that only in exceptional cases, a house in a certain block is classified in a stratum different to the one of the other houses on its block.

Table 2 shows the inconsistencies that exist between the two housing stratum measurements. About 10% of the households in the ECV2003 give a stratum that does not match the official DACD stratification.

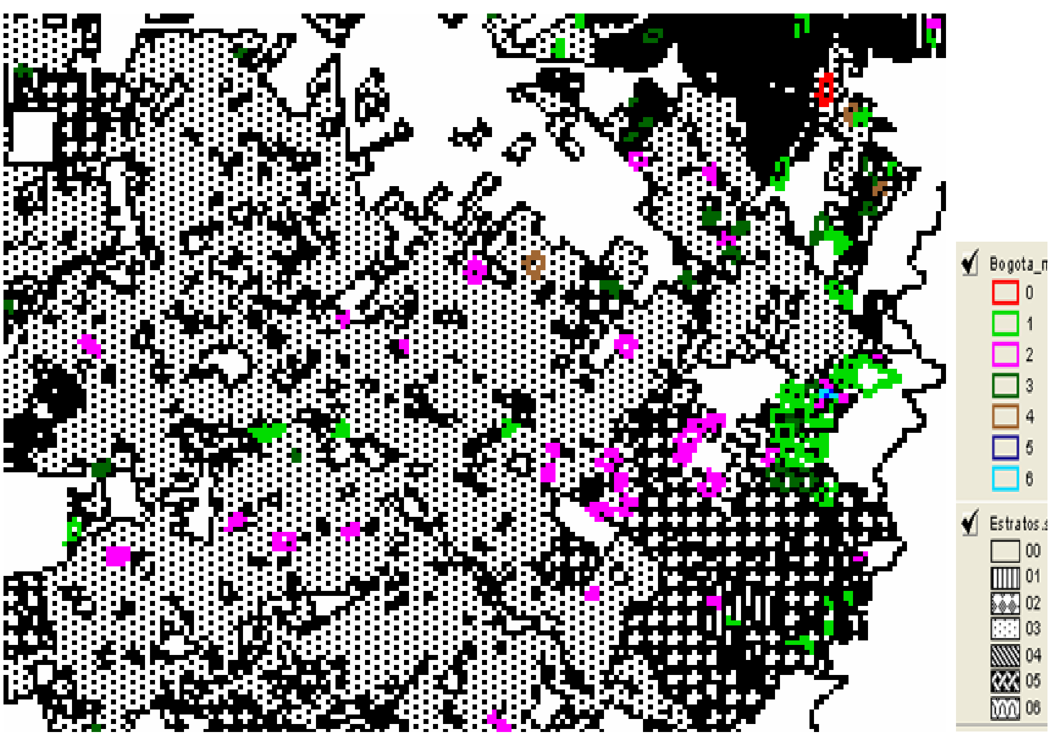
Table 2. Number of houses per stratum, ECV2003 and DACD. Bogotá, 2003.

		Stratum given by the surveyed in ECV2003							
		0	**1**	**2**	**3**	**4**	**5**	**6**	**Total**
DACD Stratum	**0**	**0**	17	125	133	59	10	16	360
	1	1	**555**	90	18	0	0	0	664
	2	0	123	**3,699**	109	9	0	0	3,940
	3	1	78	223	**5,199**	41	1	1	5,544
	4	0	31	1	77	**1,359**	32	0	1,500
	5	0	0	0	0	7	**313**	20	340
	6	0	7	0	1	2	22	**365**	397
	Total	2	811	4,138	5,537	1,477	378	402	12,745
	Match	11,490							
	Do not Match	1,255							

Source: ECV2003, DACD.

Map 1 shows a graphic illustration of the location of some of the houses stratified in ECV2003 different to DACD. These cases are more frequent in the vicinity of borders among strata, and measurement errors are also frequent inside strata.

Map 1. Measurement errors in the definition of socioeconomic stratum. Bogotá, 2003



Source: ECV2003, DACD.

With the aim of correcting the bias from measurement error, the DACD stratum is used for the instrumentation of the ECV2003 stratum. The exercise assumes that the ECV2003 stratum, $E^{ECV2003}$, and DACD's, E^{DACD}, are defined based on:

$$E_i^{ECV\,2003} = E_i + \varepsilon_i; \quad and \quad E_i^{DACD} = E_i + \eta_i \tag{3}$$

where E_i is the actual stratum for house i, and ε_i y η_i represent measurement errors.[25]

Therefore, when we talk about strata in our results section, we will mention two strata: the one from ECV2003, and its prediction using instrumental variables, with the DACD stratum as instrument. The predicted stratum is obtained by the estimation of an ordered probit model based on:

$$E_i^{ECV\,2003} = f(\alpha + X_i\beta_{1i} + E_i^{DACD}\beta_{2i} + v_i) \tag{4}$$

With the stratum predicted through this regression, new subsidies are estimated and new stratum variables and interactions with land and built square meters are constructed again.

5. Data

We use data that combines information for Bogotá city from three sources: (i) Living Standards Measurement Survey, (LSMS) by Dane, collected in 2003 (ECV2003), which provides information about households, their dwellings and neigborhoods; (ii) the Administrative Department of District Real State Appraisal of Bogotá, DACD, from where we obtain the socioeconomic stratification and the real state appraisal of Bogotá's houses, and (iii) the 1993 population census, from which we estimate the surrounding variables for Bogotá at census sector level.[26]

The left side in Map 2 illustrates the stratification in Bogotá, and the right side includes an enlargement of a city zone that shows the way how boundary dummies were constructed. In the enlargement, all the houses inside circle 6 and that are on both sides of the boundary

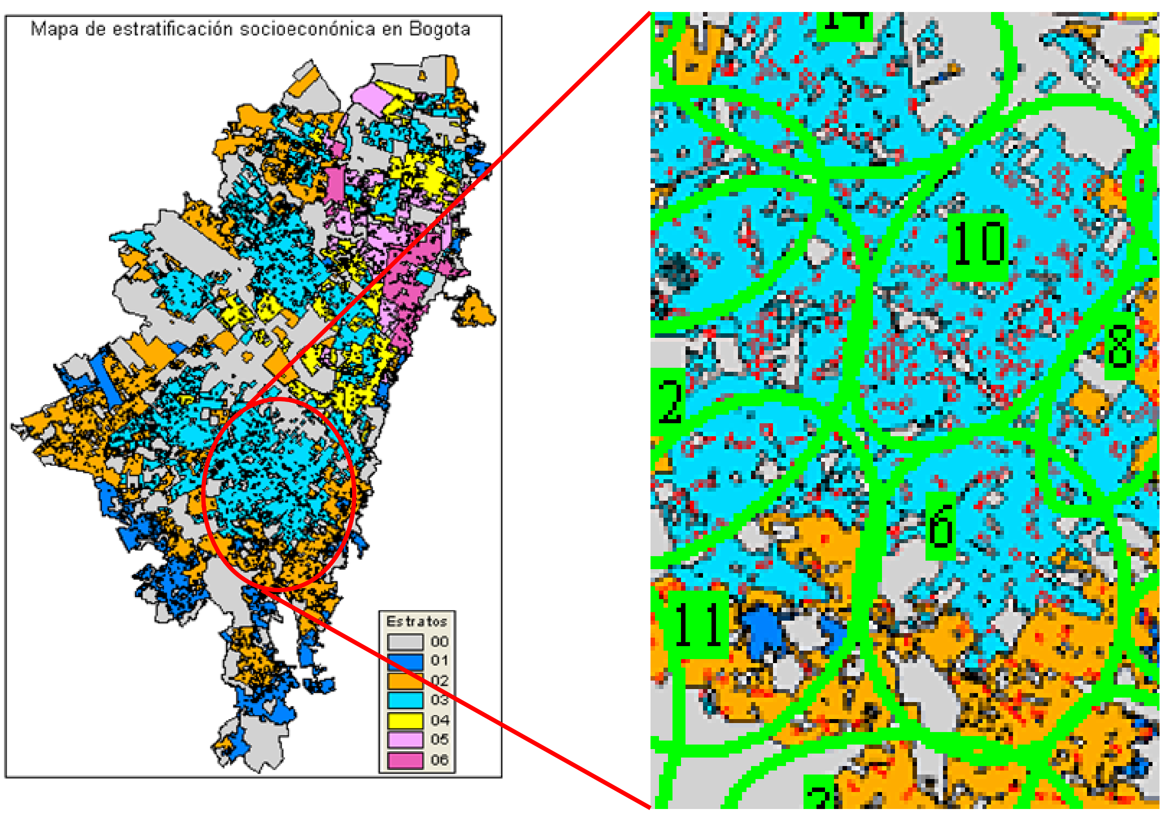
[25] Since the sources from which we get houses' stratum, namely the ECV2003 and DACD, are completely independent, the key assumption that η_i y ε_i are independent and independent from E_i and from u_{ijb}, is expected to hold in this case.

[26] Bogotá is divided into more than 600 census sectors.

between strata two (houses to the south on the strata dividing line) and three (houses to the north of said line) have K_6=1 while the other houses in the city have K_6=0.

These fixed effects to which the houses are associated, would allow us to control for the presence of mass transportation systems (not observable in the survey) available in the surroundings of boundary 6, and not available in boundary 11, also included in the enlarged map. The comparison of houses within boundary, allows us to control for the unobservable variables of the neighborhood that determine the stratum classification and that are not available as control variables. When estimating (2) only with households at a certain distance from the boundary to which they belong, we chose the household to be included in the regression, with a distance variable defined as the distance from each house to the nearest house located at the other's side of the stratum boundary.

Map 2. Stratification and boundary dummies. Bogotá, 2003



This way, and under the assumption that border location is relatively arbitrary given the large number of blocks stratification puts into only six groups, the specification used in (2) is consistent with the assumptions on which regression discontinuity design, RDD, is based, in which houses around a cut-off point (in this case, the borders between two socioeconomic strata) are usually compared and that the only difference is that houses located on one side are subject to an intervention (in this case, subsidized DPS rates), and the ones on the other side are not.[27]

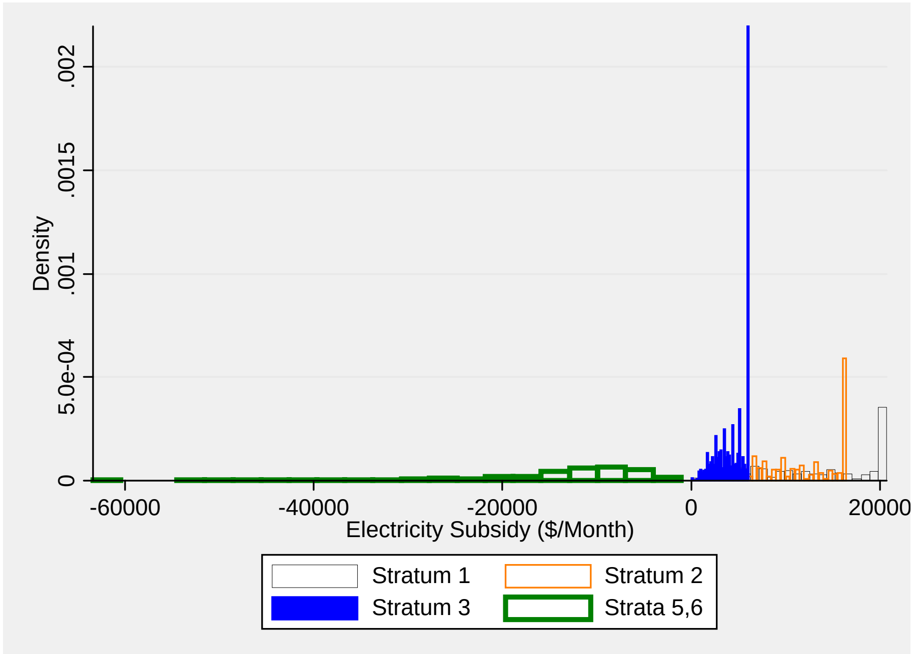
Estimation of DPS subsidy

Equation (2) assumes inhabitants in each house receive a monthly subsidy, S_i, which can be predicted by market agents on the basis of household characteristics, and particularly, on the socioeconomic stratum it is located in. Figure 1 illustrates the distribution of electricity subsidies by socioeconomic strata, which gives an idea of the probability of having a specific amount of monthly subsidy given the stratum where the house is located.

As it can be seen in the figure, a house located in stratum 1, 2 or 3 will almost surely receive a subsidy of up to $20,000 per month, while one in stratum 4 would pay the exact cost of its DPSs, thus not receiving any subsidy nor paying taxes, and in stratum 5 or 6 it would certainly pay a tax, not bounded in theory, but in practice observed to have a monthly average of $12.000. In addition to the stratum, agents in the market observe other attributes of the house and its neighborhood associated to the potential subsidy, such as its area, number of bedrooms, etc., based on which the potential DPS subsidy amount for the particular house is estimated.

Figure 1. Electricity subsidy distribution per socioeconomic stratum in Bogotá, 2003

[27] Black (1999) uses a similar approach to estimate the willingness to pay for education quality. Other RDD applications include Van der Klaauw (2002), Hahn et al. (1999), and Hahn et al. (2001). Even though there are no similar RDD applications for Colombia, there are works that take into account the spatial dimension in special house hedonic price models. Goyeneche (2003) involves the spatial dimension to examine the impact of erosion on land prices, detecting the presence of auto spatial correlation, as it does Morales (2005).



While piped water and sewerage services have three rate blocks that also define the so called subsistence, complementary and sumptuary consumptions, consumptions such as electricity and piped gas have only two blocks.[28] Figure 2 describes the bill that for each service, households in different strata have to pay according to their consumption level, and also, the respective cost of supplying the service. The marginal price of the service is the slope in each curve. For electricity, strata 1, 2 and 3 pay a subsidized rate for consumption up to the subsistence level, and a rate equal to the cost for higher consumptions, stratum 4 pays a rate equal to the cost, and strata 5 and 6 pay a rate above the cost[29].

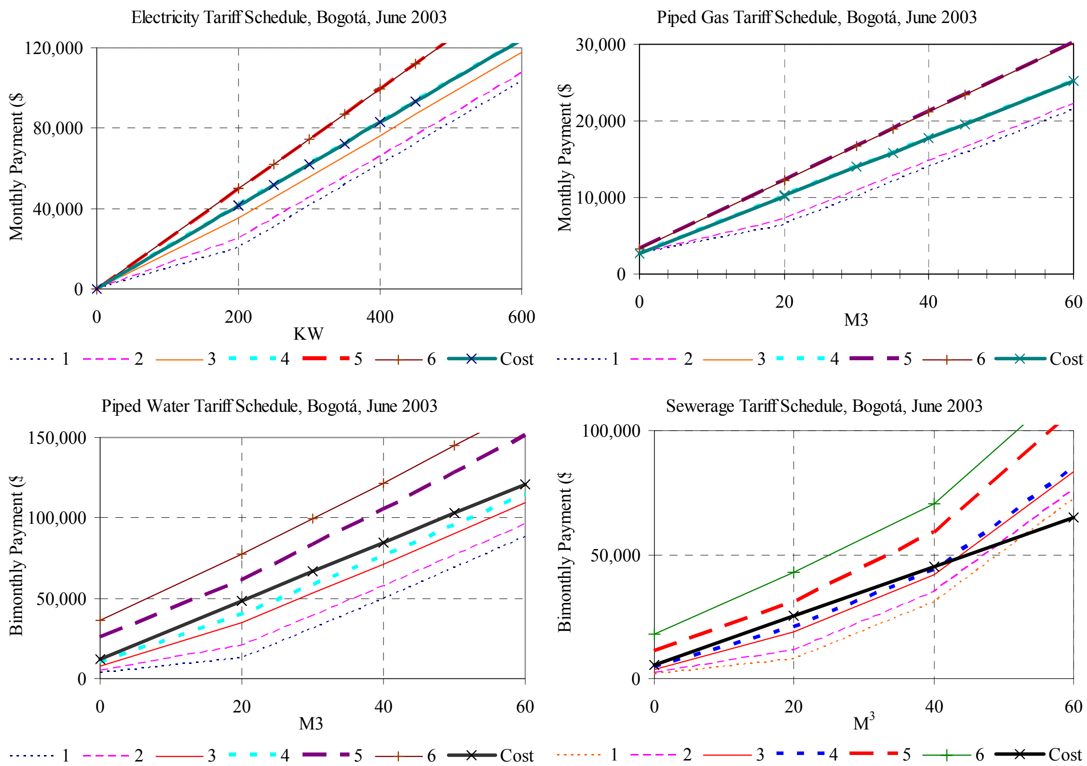
[28] For electricity, the subsistence consumption is 200 Kw, while that for piped water and sewerage is 20 cubic meters. Any consumption below those quantities has a marginal price lower than its cost for households located in the poorest strata.

[29] The value of the bill is calculated according to:

$$V^{(e)}(Q_k) = v_0^{(e)} + \sum_{n=1}^{k} p_i^{(e)} q_i; \quad Q_k = \sum_{n=1}^{k} q_i, \text{ Con } i = 1,2,\ldots,n$$

where V, corresponds to the bill value for a house located in strata *e*, $v_0^{(e)}$ is the fixed charge collected from houses located in strata *e*, $p_i^{(e)}$ is the marginal price in the price block i, for a household located in stratum *e*, q_i indicates the quantity consumed by the house in price block *i*, *n* indicates the number of intervals, and *k* the interval where *Q* is located.

Figure 2. Rates schedule for public utility services by stratum, Bogotá, 2003



Tables 3 and 4 show that for both services, most of the households are in the subsistence consumption interval. For electricity, 62% of households consume in that interval, 78% for households (the highest share) in stratum 1, and 21% (the lowest) in stratum 6. For piped water, 76% of households consume in the subsistence interval, with shares beyond 70% for households in strata one to five, and below 60% for those in stratum 6. According to these figures both subsistence consumption levels seem high, nonetheless, the one for piped water is much more generous than that for electricity.

Table 3. Households by electricity consumption ranges, Bogotá, 2003

Q(Kw)	Stratum						Total
	1	2	3	4	5	6	
<=200	75 108	381 010	456 701	87 809	26 981	12 000	1 039 609
>200	21 488	154 036	264 366	95 375	50 327	44 964	630 555
Total	96 597	535 047	721 070	183 188	77 312	56 970	1 670 184
<=200	7.22	36.65	43.93	8.45	2.60	1.15	100
>200	3.41	24.43	41.93	15.13	7.98	7.13	100
Total	5.78	32.04	43.17	10.97	4.63	3.41	100
<=200	77.75	71.21	63.34	47.93	34.90	21.06	62.25
>200	22.24	28.79	36.66	52.06	65.10	78.93	37.75
Total	100	100	100	100	100	100	100.00

Source: ECV2003

Table 4. Households by piped water consumption ranges, Bogotá, 2003

$Q(m^3)$	Stratum						Total
	1	2	3	4	5	6	
<=20	52 955	352 725	515 297	123 501	51 145	27 440	1 123 061
(20-40]	17 636	99 118	126 268	43 393	18 657	11 749	316 822
>40	559	5 974	18 126	6 221	2 978	7 034	40 893
Total	71 150	457 817	659 691	173 115	72 780	46 223	1 480 776
<=20	4.72	31.41	45.88	11.00	4.55	2.44	100
(20-40]	5.57	31.29	39.85	13.70	5.89	3.71	100
>40	1.37	14.61	44.33	15.21	7.28	17.20	100
Total	4.80	30.92	44.55	11.69	4.91	3.12	100
<=20	74.43	77.04	78.11	71.34	70.27	59.36	75.84
(20-40]	24.79	21.65	19.14	25.07	25.63	25.42	21.40
>40	0.79	1.30	2.75	3.59	4.09	15.22	2.76
Total	100	100	100	100	100	100	100

Source: ECV2003

6. Descriptive statistics and results

Table 5 presents the descriptive statistics of the variables used for our estimation. ECV2003 is rich in information about a large number of households, with approximately 12,771 interviewed in Bogotá in 2003. Unfortunately, the information available in ECV2003 to estimate all subsidies (electricity, gas, and piped water and sewerage), allows us estimate them for only 8,277 households. On the other hand, DACD information allows obtaining the real state appraisal values for 8,879 households, which once merged with the households with ECV2003 information, gives a total of 5,759 households with complete information.

It can be inferred from table 5 that the sample with complete information is not a random sample of the households in Bogotá. In particular, it includes a lower proportion of households in strata 1 and 2, and higher in strata 3, 4 and 5. It also has houses with higher real state appraisals by square meter, lower lot and built areas, and a larger proportion of houses. It has houses with more bedrooms and bathrooms, and a higher probability of having piped gas, telephone service, garage, and terrace, and in general, better house characteristics.

Table 6 shows housing prices and utility subsidies amounts by stratum.[30] These data reveal the need to control in our empirical exercise for characteristics on which the socioeconomic strata are determined, with the aim of minimizing the possibility of obtaining biased coefficients.

To estimate equation (2) we constructed 56 boundary dummies, each of which contains between 1.3% and 7.2% of the households with complete information. In constructing these variables, houses are associated only to boundaries that have no natural barriers between strata, and (since we seek smooth changes in characteristics across boundaries) that do not have a large stretch of land that separates the strata from their respective boundary (parks, industries, etc.). Next, we show the results obtained when equations (1) and (2) are estimated with the logarithm of housing prices.

Table 5. Summary Statistics

[30] The price per square meter is defined as the house price divided by the average of square meters of terrain and the built square meters.

Variable	Complete information		Incomplete information			Difference
	Mean	Std. Dev.	N	Mean	Std. Dev.	/1
Logarithm of house valuation per square meter [*]	12.13	0.6	3,585	11.91	0.6	*
Logarithm of house valuation	17.49	0.7	3,587	17.46	0.8	
House valuation	51,200,000	41,600,000	3,587	55,300,000	72,200,000	*
House valuation per square meter	225,470	158,686	3,585	185,195	153,181	*
Estimated monthly subsidy of energy	5,539	7,591	6,309	5,714	8,223	
Estimated monthly subsidy of piped water and sewerage	14,368	16,502	3,182	12,480	18,033	*
Estimated monthly subsidy of piped gas	602	1,521	7,478	479	1,661	*
Number of rooms	3.780	1.404	7,479	3.083	1.538	*
Number of bathrooms	1.681	0.864	7,468	1.471	0.814	*
House with Piped gas service	0.726	0.446	7,479	0.607	0.488	*
House with telephone	0.948	0.223	7,479	0.826	0.379	*
House with garden	0.459	0.498	7,479	0.390	0.488	*
House with court yard	0.039	0.194	7,479	0.051	0.220	*
House with garage	0.340	0.474	7,479	0.245	0.430	*
House with terrace	0.234	0.423	7,479	0.205	0.404	*
Parks in neighborhood	0.121	0.326	7,479	0.138	0.345	*
The house has suffered because of a natural disaster	0.043	0.203	7,479	0.048	0.213	
House in area vulnerable to natural disasters	0.070	0.254	7,479	0.070	0.256	
Factories in neighborhood	0.121	0.326	7,479	0.117	0.322	
Garbage collector in neighborhood	0.031	0.173	7,479	0.030	0.170	
Market places in neighborhood	0.065	0.247	7,479	0.073	0.261	
Airport in neighborhood	0.043	0.204	7,479	0.032	0.177	*
Terminals of ground transportation in neighborhood	0.031	0.173	7,479	0.034	0.181	
House close to open sewers	0.100	0.300	7,479	0.105	0.306	
Plants of residual water treatment in neighborhood	0.000	0.014	7,479	0.000	0.016	
Lines of hydrocarbon transportation in neighborhood	0.002	0.043	7,479	0.001	0.026	
House close to high tension lines of electricity transmission	0.018	0.131	7,479	0.018	0.133	
You feel safe in your neighborhood	0.668	0.471	7,479	0.689	0.463	*
Toilet inside the house	0.990	0.098	7,479	0.963	0.190	*
Daily supply of water	0.975	0.155	7,479	0.962	0.192	*
Provision of water is inside the house	0.989	0.103	7,479	0.961	0.194	*
The kitchen is a individual room	0.980	0.140	7,479	0.947	0.225	*
House[**]	0.456	0.498	7,479	0.322	0.467	*
Walls material is any of: Brick, block, stone, polished wood	0.986	0.116	7,479	0.973	0.163	*
Floor material is any of: Marmol, parque, lacquered wood	0.089	0.284	7,479	0.080	0.272	
Floor material is Carpet	0.139	0.346	7,479	0.128	0.335	
Floor material is any of: Floor tile, vinyl, tablet, wood	0.618	0.486	7,479	0.578	0.494	*
Floor material is any of: Coarse wood, table, plank	0.044	0.205	7,479	0.062	0.241	*
Floor material is any of: Cement, gravilla, earth, sand	0.110	0.313	7,479	0.152	0.359	*
House with Toilet connected to the public sewerage	0.995	0.073	7,479	0.985	0.120	*
House with potable water service	0.995	0.071	7,479	0.979	0.144	*
Number of infantile shelters by censal sector	0.066	0.296	7,479	0.072	0.387	
Number of asylums by censal sector	0.143	0.473	7,479	0.137	0.443	
Number of prisons by censal sector	0.011	0.117	7,479	0.017	0.141	*
Number of convents by censal sector	0.259	0.878	7,479	0.260	0.895	
Stratum 1	0.043	0.202	7,479	0.082	0.274	*
Stratum 2	0.289	0.453	7,479	0.349	0.477	*
Stratum 3	0.465	0.499	7,479	0.411	0.492	*
Stratum 4	0.139	0.346	7,479	0.099	0.299	*
Stratum 5	0.038	0.192	7,479	0.024	0.152	*
Stratum 6	0.025	0.157	7,479	0.036	0.186	*
Area of the land (squared meters)	104.7	89.1	3,587	138.0	459.5	*
Interaction variable Land*stratum2	27.3	70.1	3,587	46.0	96.8	*
Interaction variable Land*stratum3	52.6	77.4	3,587	57.4	100.9	*
Interaction variable Land*stratum4	13.7	47.3	3,587	9.1	44.4	*
Interaction variable Land*stratum5	2.5	20.1	3,587	4.2	110.9	
Interaction variable Land*stratum6	1.7	17.1	3,587	3.8	37.8	*
Constructed area (squared meters)	157.5	106.7	3,587	196.5	184.1	*
Interaction variable Constructed area*stratum2	40.3	84.3	3,587	68.9	115.1	*
Interaction variable Constructed area*stratum3	82.9	119.1	3,587	95.1	184.2	*
Interaction variable Constructed area*stratum4	18.7	57.1	3,587	12.3	56.9	*
Interaction variable Constructed area*stratum5	4.2	28.5	3,587	3.4	30.8	
Interaction variable Constructed area*stratum6	3.5	25.0	3,587	5.1	36.7	*
Number of Observations	5,292					

1/ Variables with difference statisticaly significant have "*". [*] The square meters used is the sum of those of land plus those of construction. [**] Dummy==1 if living in house (as opposed to an apartment, etc.)

Table 6. House price per square meter and subsidies, per socioeconomic stratum. Bogotá, 2003

Stratum	Number of Obseravtions	Housing Price/M^{2} *	Housing Price *	Subsidies**		
				Energy	Water and Sewerage	Piped Gas
1	222	85,194	20,500,000	14,658	33,031	2,441
2	1,531	129,128	28,000,000	12,044	26,700	2,176
3	2,462	199,558	48,400,000	4,859	13,083	0
4	738	396,539	76,800,000	0	8,372	0
5	202	510,514	113,000,000	-12,968	-22,385	-1,911
6	133	723,551	151,000,000	-15,046	-47,480	-1,675
Total	5,288	225,470	51,200,000	5,539	14,368	602

* Source: Administrative Department of Real State Appraisal of Bogotá.

** Source: Living Standard Measurement Survey, ECV 2003: Monthly Subsidy.

Results[31]

Results of estimating by OLS equations (1) and (2) for the logarithm of house prices are shown in table 7. The top panel shows estimates of equation (1) in the first column, and in the other columns we show estimates of equation (2) which include boundary dummies, and houses closer to the borders.[32] The top panel presents the results for each of the subsidies included and their respective square terms, and the following shows the estimates when we use the total amount of subsidies and its square, rather than each of its parts. Table 8 shows the same set of results, once the stratum is instrumented to correct for the presence of measurement error.

Estimates yield positive and statistically significant OLS coefficients of electricity subsidies, EE, and piped water and sewerage subsidies, AA, on the logarithm of housing prices: in most cases for their linear part, and for their quadratic term of EE and total subsidy. The linear and quadratic term coefficients of EE subsidy obtained by OLS with no boundary dummies and all sample (A in table 7), is slightly overestimated by about 1% and 7% respectively, with respect to its value when we control for boundary dummies (B in the

[31] The real state appraisal value is used as the house price, which is the price of the house estimated by the government and is the base for local property taxes. In ECV2003, property owners were asked about the value of their house; however, the estimated price gathered from that source is basically subjective and it is available only to the owners of the house they reside in.

[32] The reported distances (4,500 m., 1,500 m., 1,000 m., 800 m., 700 m., 600 m., 500 m., and 400 m.) are the minimum distance between each house and the closest house of the stratum found on the other side of its boundary. On average, the distances from each house to the boundary would approximately be half the distances reported in the table (this is, 2,250 m., 750 m., 500 m., 400 m., 350 m., 300 m., 250 m., and 200 m.)

table). On the other hand, as we compare houses closer and closer, for the households located 250 m. (C in the table, our RD estimates obtained not correcting for measurement error) from the boundaries, the linear and quadratic estimates increase up to 48% and 8% respectively, with respect to the estimates found when using the whole sample controlling for boundary dummies. The linear OLS coefficient of AA subsidies with no boundary dummy (A in the table), is as well overestimated, since it falls by 14% when we include the boundary dummies (B in the table), but increases again 3% when we analyze only households 250 m. from their boundaries (C in the table).[33] The OLS coefficients for the total amount of subsidies not controlling for boundary dummies (A in the table) are 9% larger than their counterpart with boundary dummies for households 250 m. from their boundaries (C in the table).

Table 7. House price model results, OLS

Dependent Variable: Logarithm of house price, OLS										
Disaggregated subsidies										
Variables/Subsidy	Without Boundaries, Equation (1)		With Boundaries, Equation (2)							
	All Sample (A)		All Sample (B)		4500 m		1500 m		1000 m	
	N = 5292	R^2=0.8715	N= 5292	R^2=0.8823	N= 4428	R^2=0.8997	N= 3935	R^2=0.8986	N= 3379	R^2=0.9011
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
Energy	3.55E-06	1.28E-06	3.51E-06	1.22E-06	1.85E-06	1.22E-06	2.57E-06	1.33E-06	3.75E-06	1.40E-06
Water and Sewerage	2.41E-06	5.32E-07	2.07E-06	5.59E-07	2.66E-06	6.25E-07	2.59E-06	6.38E-07	2.44E-06	6.68E-07
Piped Gas	-2.91E-06	4.75E-06	-2.17E-07	4.61E-06	6.03E-06	4.62E-06	7.56E-06	5.03E-06	6.67E-06	5.31E-06
$Energy^2$	1.10E-10	3.91E-11	1.02E-10	3.64E-11	9.09E-11	3.72E-11	1.04E-10	3.89E-11	9.26E-11	3.83E-11
Water and $Sewerage^2$	4.58E-13	7.22E-12	-3.63E-14	8.48E-12	-1.63E-11	1.22E-11	-1.70E-11	1.23E-11	-1.77E-11	1.26E-11
Piped Gas^2	6.32E-10	7.05E-10	2.19E-10	6.89E-10	1.82E-09	6.81E-10	2.08E-09	7.15E-10	1.95E-09	7.41E-10
Variables/Subsidy	With Boundaries, Equation (2)									
	900 m		700 m		600 m		500 m (C)		400 m	
	N= 3140	R^2=0.9038	N= 2679	R^2=0.8986	N= 2400	R^2=0.9007	N= 2085	R^2=0.9049	N= 1647	R^2=0.9026
Energy	4.43E-06	1.44E-06	4.85E-06	1.62E-06	4.63E-06	1.69E-06	5.21E-06	1.83E-06	5.54E-06	2.13E-06
Water and Sewerage	2.19E-06	6.75E-07	1.98E-06	7.74E-07	1.61E-06	8.01E-07	2.13E-06	9.10E-07	2.86E-06	1.05E-06
Piped Gas	3.22E-06	5.41E-06	-3.63E-07	5.98E-06	-3.36E-06	6.34E-06	-1.34E-06	6.70E-06	-4.56E-06	7.38E-06
$Energy^2$	1.09E-10	3.88E-11	1.08E-10	4.25E-11	1.06E-10	4.56E-11	1.10E-10	5.05E-11	1.27E-10	6.92E-11
Water and $Sewerage^2$	-1.60E-11	1.27E-11	-1.44E-11	1.50E-11	-8.06E-12	1.58E-11	-8.76E-12	2.02E-11	-2.90E-11	2.64E-11
Piped Gas^2	1.41E-09	7.48E-10	1.46E-09	8.09E-10	2.06E-09	1.04E-09	2.49E-09	1.09E-09	2.08E-09	1.23E-09
Aggregated subsidies										
Variables/Subsidy	Without Boundaries, Equation (1)		With Boundaries, Equation (2)							
	All Sample (A)		All Sample (B)		4500 m		1500 m		1000 m	
	N= 5292	R^2=0.8713	N= 5292	R^2=0.8821	N= 4341	R^2=0.9012	N= 3935	R^2=0.8983	N= 3379	R^2=0.9008
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
Total Subsidy	2.18E-06	4.29E-07	2.05E-06	4.13E-07	1.68E-06	4.51E-07	1.78E-06	4.75E-07	2.06E-06	4.81E-07
Total $Subsidy^2$	1.17E-11	4.26E-12	9.56E-12	4.08E-12	1.04E-11	4.91E-12	1.11E-11	5.01E-12	7.97E-12	4.67E-12
Variables/Subsidy	With Boundaries, Equation (2)									
	900 m		700 m		600 m		500 m (C)		400 m	
	N= 3140	R^2=0.9035	N= 2679	R^2=0.8982	N= 2400	R^2=0.9003	N= 2085	R^2=0.9044	N= 1647	R^2=0.902
Total Subsidy	1.97E-06	4.89E-07	1.82E-06	5.12E-07	1.53E-06	5.61E-07	1.99E-06	6.13E-07	2.20E-06	6.77E-07
Total $Subsidy^2$	9.04E-12	4.75E-12	1.01E-11	4.74E-12	1.22E-11	5.42E-12	1.40E-11	6.00E-12	9.30E-12	6.58E-12

[33] Nonetheless, neither of the estimates found with equation (2) results statistically different to those found with equation (1).

Robust standard errors are estimated. Results are very similar when we also adjust them for clustering either at the boundary dummy level, or at each side of the boundary dummy level.

Once the model is corrected for measurement error, and the results are compared to the ones obtained when estimating the model by OLS, it is found that for houses located approximately 250 m. from the border (C tables 7 and 8), the linear coefficient of the EE subsidy decreases by 8% and the one for AA increases by 14%, while the quadratic coefficient of EE subsidy decreases 60%, and that of the AA subsidy increases by 8%.[34] Finally, when we compare the estimate that corrects for measurement error and has the boundary dummies with the sample of up to 250 m. from the border (C in the table 8, our RD estimate obtained after correcting for measurement error), with the estimate obtained omitting the boundary dummies and with the whole sample (A in table 8), we find that the linear coefficient of EE increases 200% while that of AA decreases 20%. Nonetheless, only for distances 400 m. from the boundaries (800 m. in the table) is the linear EE coefficient statistically different from zero, while it always the case for the AA subsidy.[35]

Table 8. House price model results, IV

Dependent Variable: Logarithm of house price, IV										
Disaggregated subsidies										
Variables/Subsidy	Without Boundaries, Equation (1)		With Boundaries, Equation (2)							
	All Sample (A)		All Sample (B)		4500 m		1500 m		1000 m	
	N= 5155	R^2=0.8741	N= 5155	R^2=0.8837	N= 4343	R^2=0.9009	N= 3850	R^2=0.8992	N= 3294	R^2=0.9013
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
Energy	1.59E-06	1.23E-06	1.63E-06	1.21E-06	2.52E-07	1.20E-06	1.12E-06	1.33E-06	2.63E-06	1.42E-06
Water and Sewerage	3.01E-06	6.04E-07	2.67E-06	5.99E-07	3.09E-06	6.52E-07	3.06E-06	6.49E-07	2.66E-06	6.68E-07
Piped Gas	3.29E-06	4.68E-06	3.70E-06	4.64E-06	7.14E-06	4.70E-06	7.78E-06	5.14E-06	5.51E-06	5.49E-06
Energy^2	7.76E-11	3.87E-11	8.79E-11	3.63E-11	7.62E-11	3.66E-11	9.05E-11	3.84E-11	8.93E-11	3.95E-11
Water and Sewerage^2	-1.76E-11	1.20E-11	-1.89E-11	1.18E-11	-2.68E-11	1.28E-11	-2.82E-11	1.27E-11	-2.31E-11	1.27E-11
Piped Gas^2	1.80E-09	7.34E-10	1.51E-09	7.15E-10	2.37E-09	6.96E-10	2.47E-09	7.41E-10	2.16E-09	7.81E-10
Variables/Subsidy	With Boundaries, Equation (2)									
	900 m		700 m		600 m		500 m (C)		400 m	
	N= 2840	R^2=0.9017	N= 2597	R^2=0.9012	N= 2318	R^2=0.902	N= 2002	R^2=0.9057	N= 1569	R^2=0.9044
Energy	3.51E-06	1.57E-06	3.61E-06	1.65E-06	4.21E-06	1.78E-06	4.78E-06	1.97E-06	4.57E-06	2.25E-06
Water and Sewerage	2.65E-06	7.29E-07	2.20E-06	7.18E-07	2.09E-06	8.00E-07	2.42E-06	9.35E-07	3.13E-06	1.01E-06
Piped Gas	-9.92E-07	5.96E-06	-9.71E-07	6.14E-06	-5.07E-06	6.67E-06	-6.44E-06	7.16E-06	-9.90E-06	7.90E-06
Energy^2	9.89E-11	4.35E-11	6.22E-11	4.44E-11	5.08E-11	4.99E-11	4.42E-11	5.81E-11	4.21E-11	7.61E-11
Water and Sewerage^2	-3.78E-11	1.44E-11	-2.95E-11	1.39E-11	-1.86E-11	1.65E-11	-9.47E-12	2.17E-11	-1.99E-11	2.67E-11
Piped Gas^2	1.50E-09	8.12E-10	1.18E-09	8.28E-10	1.74E-09	1.01E-09	2.06E-09	1.06E-09	1.43E-09	1.18E-09

[34] In this case, these pairs of differences are not either statistically different from zero.

[35] Again, once correcting for measurement error, neither of the estimates found with equation (2) with the whole sample or 500 m. from the boundary, results statistically different to those found with equation (1). Significance of the coefficients is robust to regressions ran correcting for clustering when households in each boundary and stratum (that is, each side of the boundary) define a group, or when each boundary (regardless of the side of the boundary) defines a group. For example, in the first case, the *t*-statistic of our RD estimate (C in table 8) on the subsidy of energy is 2.3, while that of our RD estimate on the subsidy of water is 1.9. In the second case, these figures are 2.3 and 2.2 for our RD coefficients of EE and AA respectively.

Aggregated subsidies										
Variables/Subsidy	Without Boundaries, Equation (1)		With Boundaries, Equation (2)							
	All Sample (A)		All Sample (B)		4500 m		1500 m		1000 m	
	N= 5153	R^2=0.874	N= 5153	R^2=0.8836	N= 3848	R^2=0.8992	N= 3848	R^2=0.8992	N= 3292	R^2=0.9011
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
Total Subsidy	2.13E-06	4.42E-07	1.88E-06	4.27E-07	1.61E-06	4.55E-07	1.79E-06	4.77E-07	2.00E-06	4.89E-07
Total Subsidy^2	5.85E-12	4.75E-12	5.77E-12	4.52E-12	6.61E-12	4.77E-12	6.38E-12	4.87E-12	5.91E-12	4.70E-12
Variables/Subsidy	With Boundaries, Equation (2)									
	900 m		700 m		600 m		500 m (C)		400 m	
	N= 2838	R^2=0.9014	N= 2595	R^2=0.9008	N= 2317	R^2=0.9022	N= 2002	R^2=0.9054	N= 1569	R^2=0.904
Total Subsidy	1.95E-06	5.36E-07	1.86E-06	5.47E-07	1.98E-06	6.42E-07	2.40E-06	7.29E-07	2.77E-06	7.30E-07
Total Subsidy^2	-1.74E-13	5.27E-12	-1.32E-12	5.33E-12	1.52E-12	6.72E-12	4.26E-12	7.93E-12	-2.17E-13	7.43E-12

Robust standard errors are estimated. Results are very similar when we also adjust them for clustering either at the boundary dummy level, or at each side of the boundary dummy level.

In sum, the final estimate of the linear EE coefficient (C in table 8) is 35% larger that the estimate obtained by OLS with the whole sample (A in table 7), since the OLS estimate is underestimated for not restricting the sample to the one closest to the boundaries, and overestimated for measurement error. On the other hand, the final estimate of the linear AA coefficient (C in table 8) is similar to the estimate obtained by OLS with the whole sample (A in table 7), nonetheless, the OLS estimate is overestimated for not including the boundary dummies, underestimated for not restricting the sample to the one closest to the boundaries, and underestimated for measurement error.[36] In short, the inclusion of boundary fixed effects, the comparison of closer houses, and the correction for measurement error, are all playing a role in getting us closer to obtaining unbiased estimators of the effect of DPS subsidies on housing prices.[37]

Table 9 shows the necessary information for the calculation of the elasticity of house prices per square meter with respect to each one of the subsidies, using the coefficients obtained in columns A, B and C of tables 7 and 8. Differences in the estimated elasticities include differences in both the linear and quadratic coefficients of tables 7 and 8. Here again, although our RD estimates do not differ significantly from the basic estimates obtained by OLS, including in the estimation non comparable households, omitting variables, and not

[36] The other estimates found when equation (1) is estimated (column A in table 7) are included in Annex 4. As it is shown, the value of houses increases with better characteristics such as their number of rooms, of bathrooms, if the house has piped gas, garden, garage, kitchen in an individual room, better floor materials, toilet connected to public sewerage, if there are parks in their neighborhood, and there are public services like ground transportation, no open sewers, no garbage collectors, or potable water, if the house is located in a better stratum, and if the are of land, or constructed, is larger.

[37] Nonetheless, the coefficients obtained with equation (2) with the whole sample or 500 m. from the boundary, and those obtained with equation (1) are not statistically different.

correcting for measurement error, are all effects that bias the estimates in counterbalancing ways that become uncovered with the comparison of the total change in the estimates. As shown in the table, our RD estimates are very similar for EE (2.97%) and AA (2.95%).

Table 9. Implicit elasticities between subsidy and house prices/1

Variable/ Subsidy	Average Subsidy (only sample of households* who receive subsidies)	Average Contribution (only sample of households** who pay contributions)	Average Subsidy (all households***)	Elasticities							
				OLS			IV			(6)-(1)	
				All Sample		500 m.	All Sample		**500 m.**		
				Without BD	With BD	With BD	Without BD	With BD	**With BD**	Diff.	t-stat
				(1)	(2)	(3)	(4)	(5)	**(6)**		
Energy	8,108	-14,445	5,634	0.0270	0.0263	0.0363	0.0139	0.0148	**0.0297**	10%	0.18
				0.0081	0.0079	0.0120	0.0077	0.0075	**0.0126**		
Water and Sewerage	17,126	-33,622	13,659	0.0331	0.0283	0.0258	0.0345	0.0294	**0.0295**	-11%	-0.26
				0.0083	0.0079	0.0111	0.0077	0.0077	**0.0108**		
Total Subsidies	24,589	-48,954	19,686	0.0520	0.0411	0.0505	0.0465	0.0415	**0.0505**	-3%	-0.09
				0.0090	0.0087	0.0122	0.0088	0.0089	**0.0123**		

1/ Results are obtained with the sample located at an average 250 m. from the border (500 m. between each house and the closest one from another stratum), and correcting for measurement error. Robust standard errors. * Each line includes all households who reported the amount paid last month for its consumption, and received subsidies, of that respective service (EE, AA or both). ** Each line includes all households who reported the amount paid last month for its consumption, and paid contributions, of that respective service (EE, AA or both). *** Each line includes all households who reported the amount paid last month for its consumption, regardless of whether they received subsidies or paid contributions in any service (EE and AA).

With the aim of estimating the subsidy received by households, net of its effect on housing prices, in table 10 we present estimates of the current net present value, NPV, for all subsidies and contributions, discounted at 10% annual real interest rates in the top panel, and at 15% annual real interest rates in the lower, and the changes that a 100% variation in subsidies implies on house prices based on the elasticity estimated in table 9, Δvaluation.[38]

When the NPV is compared with ΔA, using a 10% annual real interest rate we find that both magnitudes are similar, which implies that the DPS subsidies are transferred almost entirely to housing prices.

Table 10. Comparison of the net present value of subsidies with their incidence on housing prices*

[38] A 100% subsidy variation approximately represents 75%, 80% and 40% of the standard deviations of EE, AA, and piped gas subsidies respectively. On the other hand, households in the survey report mortgage payments around 1.05% of their houses appraisal, which is close to the 1.09% they would have to pay as annuity for a 15 years (the standard duration of mortgage loans in Colombia) loan at a 10% annual interest rate. Currently, rates on mortgage loans reached historical lows of inflation (always beyond 5%) plus 7%. Clearly our estimates are expected values, since there is uncertainty on several variables like interest rates, opportunity cost of households, and subsidies themselves among others. Finally, we estimate the net present value of subsidies as the one of the perpetuity of the mean subsidy reported in table 8 at the reference interest rate. For energy, we have that NPV of subsidies is $8108/[(1+r)^{1/N}-1)]$, where r is 0.10 or 0.15, and N is 12.

Table of average results for annual discount rate of 10%							
Variable/ Subsidy	Elasticity	NPV		Δvaluation		Δvaluation/NPV	
		Subsidy	Contribution	Due to Change in Subsidy	Due to Change in Contribution	Subsidy	Contribution
Energy, EE	0.0297	1,016,810	-1,811,439	1,320,298	4,014,419	1.30	-2.22
Water and Sewerage, AA	0.0295	2,147,633	-4,216,391	1,455,403	3,808,256	0.68	-0.90
EE+AA		3,164,444	-6,027,830	2,775,701	7,822,675	0.88	-1.30
Total Subsidies	0.0505	3,083,605	-6,139,050	2,497,108	6,520,789	0.81	-1.06

Table of average results for annual discount rate of 15%							
Variable/ Subsidy	Elasticity	NPV		Δvaluation		Δvaluation/NPV	
		Subsidy	Contribution	Due to Change in Subsidy	Due to Change in Contribution	Subsidy	Contribution
Energy, EE	0.0297	692,125	-1,233,015	1,320,298	4,014,419	1.91	-3.26
Water and Sewerage, AA	0.0295	1,461,857	-2,870,024	1,455,403	3,808,256	1.00	-1.33
EE+AA		2,153,982	-4,103,039	2,775,701	7,822,675	1.29	-1.91
Total Subsidies	0.0505	2,098,956	-4,178,745	2,497,108	6,520,789	1.19	-1.56

* Net present values of subsidies and contributions, as well as changes in valuations, are in Colombian pesos of 2003. Results are obtained with the sample located at an average 250 m from the border (500 m. between each house and the closest one from another stratum), and correcting for measurement error. The change in house valuation, Δvaluation, is generated by a 100% change in subsidy.

Finally, table 11 illustrates not only how net subsidy becomes actually a tax, but also how it is distributed by income decile, for both, EE and AA. Only when the EE subsidy is discounted at a 10% annual real interest rate, a positive subsidy for the poorest households is found. However, that is the population expected to have a higher opportunity cost of money, for which it would be expected to be the one more likely to discount subsidy flows at a higher rate. There are important reductions in AA subsidies due to housing capitalization in the case or AA, where only the poorest 20% of the population end up receiving a somewhat relevant amount.

In short, the estimates obtained allow us concluding that DPS subsidies are almost entirely transferred to the value of the house that receives them, without generating an apparent benefit on the net, only distorting housing prices.

Table 11. Distribution of DPS subsidies net of their incidence on house value. Bogotá, 2003*

Energy, EE

Decile	Monthly Amount of Subsidies ($)	Subsidio % Income	Discount Rate = 0.10		Discount Rate = 0.15	
			Amount of Net Subsidy	Net Subsidy % of Income	Amount of Net Subsidy	Net Subsidy % of Income
1	381,543,074	5.5%	7,018,174	0.1%	-168,676,493	-2.4%
2	488,009,656	2.2%	16,445,345	0.1%	-204,771,828	-0.9%
3	545,908,526	1.7%	-30,098,973	-0.1%	-300,311,872	-0.9%
4	617,593,442	1.3%	24,199,277	0.1%	-254,169,879	-0.6%
5	674,633,707	1.0%	-6,097,110	-0.01%	-325,437,100	-0.5%
6	629,887,029	0.7%	-58,899,267	-0.1%	-382,018,229	-0.4%
7	612,863,369	0.5%	-155,701,525	-0.1%	-516,245,621	-0.4%
8	591,676,242	0.3%	-280,949,748	-0.2%	-690,310,420	-0.4%
9	463,921,284	0.2%	-286,651,201	-0.1%	-638,754,762	-0.3%
10	224,639,582	0.1%	-231,103,448	-0.1%	-444,898,606	-0.1%
Total	5,230,675,911	0.43%	-1,001,838,476	-0.08%	-3,925,594,811	-0.32%

Water and Sewerage, AA

Decile	Monthly Amount of Subsidies ($)	Subsidio % Income	Discount Rate = 0.10		Discount Rate = 0.15	
			Amount of Net Subsidy	Net Subsidy % of Income	Amount of Net Subsidy	Net Subsidy % of Income
1	959,510,155	13.8%	543,167,767	7.8%	347,856,128	5.0%
2	1,171,353,736	5.4%	682,522,562	3.1%	453,205,078	2.1%
3	1,323,456,238	4.1%	716,325,415	2.2%	431,512,307	1.3%
4	1,449,931,661	3.1%	795,147,452	1.7%	487,979,104	1.1%
5	1,598,213,756	2.4%	874,442,736	1.3%	534,911,601	0.8%
6	1,558,287,689	1.8%	786,617,779	0.9%	424,616,910	0.5%
7	1,530,139,810	1.3%	610,165,333	0.5%	178,592,787	0.2%
8	1,494,818,640	0.8%	428,601,977	0.2%	-71,574,625	-0.04%
9	1,356,714,458	0.5%	237,980,898	0.1%	-286,832,010	-0.1%
10	874,734,539	0.2%	-189,031,175	-0.05%	-688,057,709	-0.2%
Total	13,317,160,684	1.09%	5,485,940,744	0.45%	1,812,209,571	0.15%

* Results are obtained with the sample located at an average 250 m from the border (500 m between each house and the closest one from another stratum), and correcting for measurement error.

Results for rent prices

The ECV asks households who pay rent for their monthly paiment. In addition, it asks those who live in their own houses for the rental amount they consider the house would generate if it was rented. Using as dependent variable the logarithm of the rents reported in either case, we repeat the exercise previously done. The results show a positive relation between EE and AA subsidies and the logarithm of the rent paid by households.

Based on our RD estimates obtained in a similar way as we did for house valuation, we find that the increase in the monthly rent due to subsidies is 2.45 and 1.04 times, the amount of EE and AA subsidies received respectively.

Potential biases due to capitalization effects of taxes or other subsidies

Although our estimates account for most of the relevant necessary factors to obtain unbiased coefficients, there are still other factors not accounted for that might be driving our results. Two factors are of special relevance: property taxes and other sort of stratum targeted subsidies.[39]

In the case of property tax, Bogotá since 1993 until late 2003, right after the ECV2003 survey took place, implemented a property tax that had higher rates for houses in higher strata, and within strata, to those with larger built areas. In order to assess whether our results are driven by property taxes rather than by DPS subsidies, we include in equation the log of the effective property tax rate as an additional control variable. We also got estimates that included a dummy variable equal to one if the household was beneficiary of the subsidized regime, SR, the public health insurance targeted indirectly according to the socioeconomic stratum to the poorest population.[40] Beneficiaries of the SR receive annually nearly 1% of GDP in health insurance subsidies.

Table 12 presents the result once we control for property tax and the SR. The coefficient of the linear term of EE becomes slightly smaller while that of AA becomes larger, and their statistical significance is not as robust as found. Nonetheless, even for the case in which both the logarithm of the effective property tax tariff and the affiliation to the subsidized regimen variables are included, each pair of the coefficients on EE and AA are jointly significant at levels higher than 90%.

[39] We also checked whether including a measure of the average subsidy on each side of the boundaries would change our results. We obtained LLR estimates of energy subsidies evaluated at each side of each boundary, conditional on being near each respective boundary, Results remain mostly unaffected.

[40] SR is targeted according to a Proxy-means test denominated Sisben, which is highly correlated to socioeconomic strata.

On the other hand, our results suggest some evidence of property tax capitalization, with a negative and significant coefficient for the property tax effective tariff.[41] In addition, the inclusion of the SR has negligible effects on the relevant coefficients.[42]

Table 12. House price model results with additional controls

Variable	1000		800		700		600		500	
	Coefficient	*t*	Coefficient	*t*	Coefficient	*t*	Coefficient	*t*	Coefficient	*t*
Subsidy of Energy	2.41E-06	1.56	3.02E-06	1.77	3.61E-06	1.95	3.78E-06	1.94	4.01E-06	1.86
Subsidy of Piped water and sewerage	2.68E-06	2.83	2.92E-06	2.84	2.79E-06	2.55	2.80E-06	1.60	2.89E-06	1.63
Subsidy of Piped gas	5.58E-07	0.08	-5.82E-06	-0.77	-4.51E-06	-0.56	-6.73E-06	-0.77	-7.36E-06	-0.75
Subsidy of Energy squared	7.12E-11	1.69	7.20E-11	1.56	3.40E-11	0.71	2.14E-11	0.35	1.67E-12	0.02
Subsidy of Piped water and sewerage squared	-1.47E-11	-0.97	-2.95E-11	-1.70	-1.76E-11	-0.98	-1.06E-11	-0.32	-4.77E-12	-0.14
Subsidy of Piped gas squared	4.13E-10	0.45	-1.12E-10	-0.11	-4.37E-10	-0.45	-5.23E-10	-0.40	-1.53E-10	-0.11
Ln(τ)	-0.024	-1.79	-0.038	-2.74	-0.038	-2.68	-0.030	-2.07	-0.036	-2.33
Variable	1000		800		700		600		500	
	Coefficient	*t*	Coefficient	*t*	Coefficient	*t*	Coefficient	*t*	Coefficient	*t*
Subsidy of Energy	2.33E-06	1.50	2.99E-06	1.75	3.46E-06	1.88	3.59E-06	1.84	3.72E-06	1.72
Subsidy of Piped water and sewerage	2.69E-06	2.83	2.90E-06	2.81	2.76E-06	2.51	2.80E-06	1.59	2.89E-06	1.61
Subsidy of Piped gas	3.52E-07	0.05	-5.78E-06	-0.76	-4.26E-06	-0.53	-6.45E-06	-0.74	-7.36E-06	-0.76
Subsidy of Energy squared	6.96E-11	1.65	7.14E-11	1.55	3.15E-11	0.66	1.86E-11	0.30	-2.72E-12	-0.04
Subsidy of Piped water and sewerage squared	-1.47E-11	-0.97	-2.99E-11	-1.72	-1.85E-11	-1.04	-1.26E-11	-0.38	-7.12E-12	-0.21
Subsidy of Piped gas squared	4.09E-10	0.44	-9.03E-11	-0.09	-3.83E-10	-0.40	-4.65E-10	-0.35	-1.09E-10	-0.07
Ln(τ)	-0.025	-1.80	-0.0381	-2.7	-0.0375	-2.68	-0.030	-2.10	-0.037	-2.38
RS	-0.037	-1.47	-0.032	-1.20	-0.049	-1.68	-0.042	-1.62	-0.051	-1.75

[*] The dependent variable is the logarithm of the house appraisal. Results are the equivalent to those reported in table 8 once Ln(τ) and RS are included. *t* statistics are estimated based on robust standard errors.

Other potential biases

Despite we consider our results make a good case in providing evidence of capitalization of public utility subsidies on house prices, our methodology is not free of caveats. First, there are several issues standard to hedonic regressions that might be generating biases in our estimates such as the presence of substantial heterogeneity across households, spatial correlation, etc. Secondly, although the evidence provided supports to a large extent the validity of the RD assumptions (i) and (ii) specified in section 4, namely having similar houses across boundaries subject to different subsidies, in the case of assumption (ii) there would still need to be proven whether unobservable characteristics change smoothly around

[41] We used as well and augmented sample that included both the households who reported the amount paid as property tax, as well as those who did not report it, assigning them the theoretic tariff to the later, and results did not change significantly.

[42] Intuitively though, one could expect in the future the inclusion of the SR to have a positive effect on house prices, as the recently implemented "New Sisben" score makes households living in a house that belongs to a lower stratum to have smaller the score used to target the SR, thus increasing the probability of being beneficiary once a households moves just across the borders between strata (in particular when households move from 1-2 strata to 3 and higher or viceversa), affecting house prices just in a similar way public utility subsidies do.

the boundaries as well. In addition, assumptions (iii) and (iv), imply more demanding requirements in our case.

Assumption (ii) would not be satisfied if for example differences in preferences across races could lead individuals from different races to segregate across the boundaries. Since people would value differently the network each neighborhood offers them, this could be an example of an unobservable characteristic we would not be controlling for, that could change discontinuously around the boundaries. In general, since people can estimate in advance the benefits they could receive from locating at any side of the boundaries, one could argue that some sort of sorting around the boundaries on unobservable characteristics, such as households' preferences, should be taking place in practice. As long as such sorting will very likely become a characteristic that affects house prices in a discontinuous way around boundaries, the mechanics that generates this sorting would imply a violation of assumptions (iv), which in this context would come along with a violation of assumption (ii), and in some cases, (iii).

The effect of eliminating Stratification as targeting mechanism

Given our results, a natural question is: who would be the winners and losers of abolishing the targeting system of subsidies to public utility services as it currently is in urban Colombia? The answer depends on whether households are tenants or owners of houses. If a household is a tenant in the house it is living, then once the targeting system were abolished, they would receive no public utility services subsidies, but end up paying a lower rent, in a similar amount to the subsidy previously received, thus staying relatively indifferent with respect to its previous situation. On the other hand, if the household is the owner of the house, then its wealth would decrease (increase) in an amount equivalent to the present value of the subsidies (taxes) on public utility services it was receiving (paying) through a higher rent paid by their tenants.

We should bear in mind that our baseline scenario is the current one, in which public expenditure in public utility domiciliary services is playing no role but distorting relative houses prices. Poor households have to pay in advance in the price of their houses, the present value of the flow of subsidies their houses provide, as well as the wealthy households pay for their houses a lower price, in an amount equivalent to the present value of the flow of taxes their houses demand.

Paradoxically, although the current subsidies scheme as currently is, is playing no role, abolishing it would not be indifferent to individuals. Table 13 illustrates the distribution of owner and tenant households by socioeconomic stratum in Bogotá.

As the table shows, the subsidies policy has required about half of the households living in strata one to three (those owners of the house they live in), to pay a price for their houses that is higher than what it would have been in the absence of the subsidies scheme. Eliminating current subsidies scheme, and adopting a flat rate equivalent to the marginal cost to houses in any strata, would be equivalent to expropriating these households the value they paid, or had paid, for their houses under the previous conditions. Furthermore, as the table shows, the median voter would be a loser of abolishing the current subsidies scheme, what anticipates a political economy constraint to reforming it. Put another way, if the current scheme were to be abolished, households owners of houses located in the poorest strata would require to be compensated by an amount equivalent to the distortion the government had caused with the scheme itself (which seems budgetary unfeasible).

Table 13. House ownership by socioeconomic stratum. Bogotá, 2003

Stratum	Number of Houses		Distribution by stratum		Ownership by stratum		
	Owner	Tenant	Owner	Tenant	Owner	Tenant	Total
0	0	1	0.0	0.0	21.3	78.7	100
1	330	445	5.5	6.6	42.6	57.4	100
2	2,287	2,010	38.2	29.7	53.2	46.8	100
3	2,634	2,844	44.0	42.1	48.1	51.9	100
4	435	828	7.3	12.2	34.5	65.5	100
5	189	356	3.2	5.3	34.7	65.3	100
6	107	279	1.8	4.1	27.7	72.3	100
Total	5,982	6,764	100.0	100.0	46.9	53.1	100

Clearly, eliminating the current subsidies scheme would be regressive, but beyond the cost of keeping or modifying the current subsidies scheme, the question here is whether the government is achieving with these subsidies what it sought. According to Law 142 of 1994, the government sought to "establish a regime of rates proportional to low income sectors, according to principles of equity and solidarity", and continues arguing: "the subsidies scheme, will be provided so that low income people can afford to pay the rates of domiciliary public utility services that cover their basic needs". If savings due to subsidies are being paid to a distorted, because of the subsidy, house price, or rental value, then none of these goals is being achieved with the current scheme.

Still, as the current subsidies scheme goes on, the government keeps allowing the assignment of nearly 0.7% of GDP in gross subsidies to households in strata 1, 2 and 3, 0.3% of which come out of its budget, and 0.4% from households living in strata 5 and 6, and from commercial, public and industrial sectors, ending up doing nothing but distorting relative house prices and the efficient assignment of factor in the productive sector, even though it has several different mechanisms to comply with the above mentioned purposes.
There are several unfavorable side effects of the stratification scheme. On one side, there are perverse incentives to individuals seeking to become targeted by public authorities in charge of assigning subsidies, which has led among other things, and according to the ECV1997 and ECV2003, to an increase in the household living in strata 1 and 2 of 100% and 14% between 1997 and 2003, while those living in strata 4 and 5 decreased 10% and 43% respectively. These changes will have direct effects on Colombian proxy-means test targeting system, which recently became highly correlated to socioeconomic stratification.

On the other side, stratification leads to segregated communities of the poorest and the richest. Reversing such segregation would seem unfeasible in we accept as reasonable the sentence by Grodzins (1957) as quoted by Schelling (1972): "Once an urban area begins to swing from mainly white to mainly black, the change is rarely reversed".[43]

[43] Cutler and Glaeser (1997), Kremer (1997), and Card and Rothstein (2006) among others, find evidence of effects of segregation on inequality (higher segregation implying higher differences in several outcomes between segregated groups), mobility, and test scores (higher segregation implying higher test scores gap between groups)

Other schemes, based on instruments like the SISBEN, a proxy-means test that allows ordering houses from the poorest to the richest according to their permanent income, could be consider for targeting subsidies to public utility services. Such mechanism is being used in Colombia to target demand subsidies to health, by providing health insurance for the poor. As we mentioned previously, the government expends annually about 1.0% of GDP in that program; thus, resources currently located to subsidize public utility services would suffice to increase this budget in 70%.[44] In addition, according to Medina and Morales (2007), deadweight losses associated to electricity and water subsidies amount nearly to 5% and 10% of their respective subsidies. This implies that if we eliminated subsidies to public utility services, and transferred to households the required compensated variation, households would end up as well as they were previously with their subsidies, housing prices would not be distorted, and we would save up to US$35 millions per year previously spent in efficiency losses, much less than what we would require to keep the Sisben mechanism working, estimated in about US$7 million every five years.

If the government wanted to eliminate stratification as its targeting mechanism, an option to face the potential political economy restrictions, would be to do it on a very long period of time, say 20 years, while simultaneously introducing another mechanism, such as the Sisben.

On the other hand, policies proposing to lower the level of basic consumption subject to subsidies, would not per se improve targeting, due to the high level of subsidies capitalization, but at least they would reduce the magnitude of the distortion.

6. Conclusions

The cross subsidies schemes have been widely used in Latin-American countries to deliver domiciliary public utility services (electricity, piped water and sewerage services, and piped

[44] Benefits from better access to health services, as opposed to public utility services, is less likely to end up being auctioned in the market, and more likely to comply with the goals sought by the government in its public utility services policy.

gas) to low income population at rates that are below their costs, whereas the higher income population contributes by paying rates above the costs. While there is a consensus in most countries on the relevance of subsidizing the consumption of said services, their policies have focused into minimizing the inefficiencies implied in subsidies and making their targeting more effective.

In Colombia there is a cross subsidy system which charges subsidized rates to the households who live in houses located in strata associated to low wealth levels, and taxed rates to households that live in strata associated to high wealth levels.

Even if the consumption of domiciliary public utility services is nontransferable, this document assesses the hypothesis that the flow of subsidies that potentially could be received from a specific house, could be discounted by housing market agents, so that most of them end up being transferred to the prices of the houses that generate the subsidies, rather than staying in the pockets of households that reside in them.

In order to estimate the effect that subsidies to domiciliary public utility services can have on houses value, the prices for houses on both sides of the boundary of different socioeconomic strata are compared, this is, houses subject to different public utility service rates, and it is found that the increment in house value estimated because of subsidies, is similar in magnitude to the present value of the flow of subsidies discounted at reasonable market rates. Likely effects of these subsidies are found on the rent amount.

Although the results found include information only for Bogotá, we think that the same would be consistent with the current situation in the main Colombian cities. The above takes us to conclude that the functions of financing subsidies for the poor population through public spending in domiciliary public utility services in Colombia is being achieved, if anything, in a very limited way. Most of the fiscal effort on this subject has as its final effect, the distortion of houses prices in different socioeconomic strata. While the system assigns 0.7% of GDP each year in supposed gross subsidies to domiciliary public utility services in Colombia, the only thing they end up doing is introducing an additional characteristic (subsidies, which would not exist without government intervention) into a set of houses, and moving the housing market to auctioning such characteristic, with the consequent distortion on houses relative prices.

The evidence contained in this document calls for a review of the subsidy targeting policies for domiciliary public utility services in Colombia and other countries in the region that have similar schemes. It is important to continue gathering evidence that allows generating consensus around the benefits and limitations of this type of schemes, as an eventual review of them should at first, face important political economy constraints, which have been and will continue to be a bottle neck in the achievement of more efficient and better targeted subsidies.

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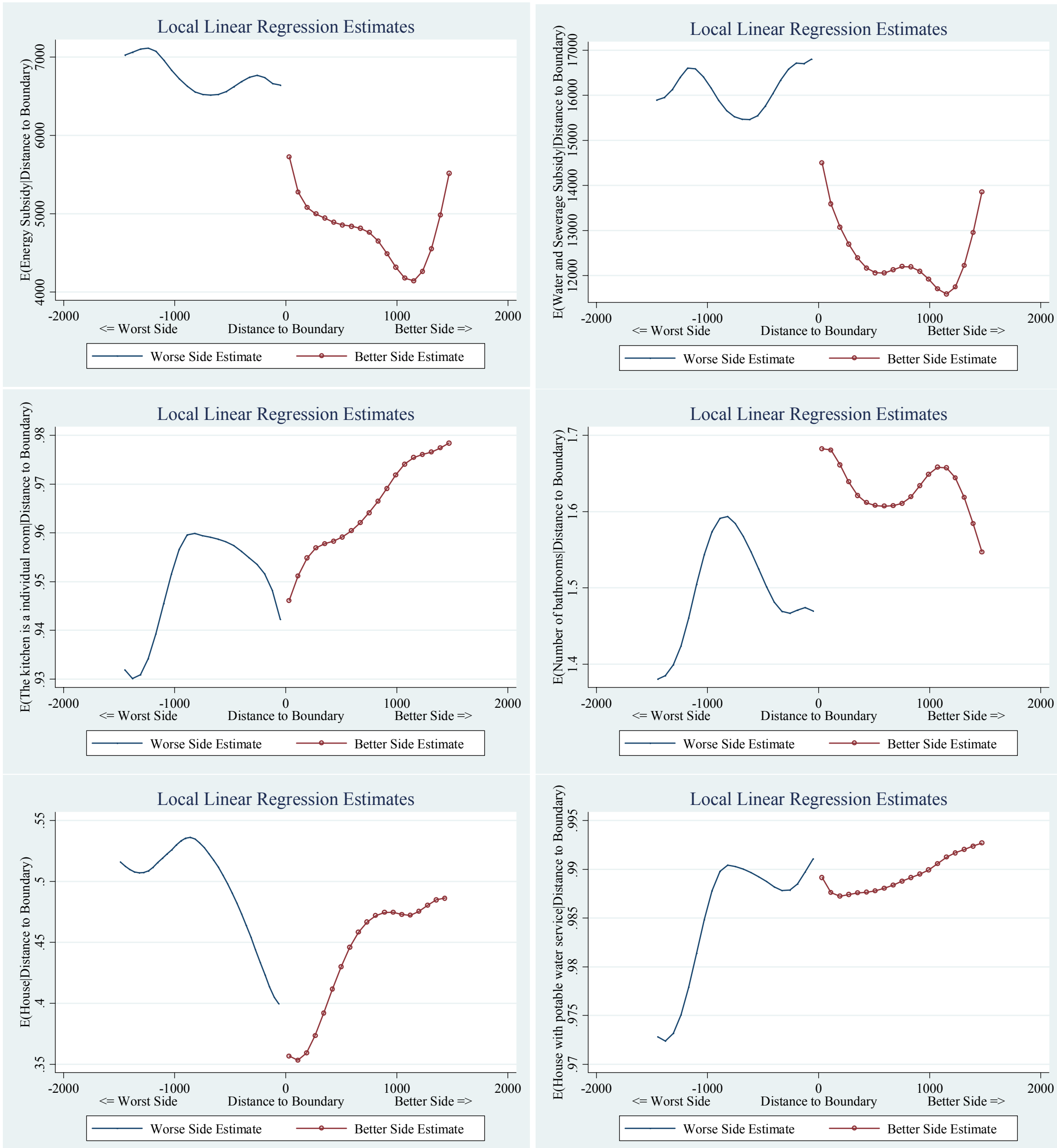
Annex 1. T-statistics obtained when comparing means of characteristics between the better and worse sides of the boundaries

Variable	Distance (meters)				
	750	500	250	150	125
House valuation	-0.68	-0.85	1.30	1.09	-1.48
House valuation per square meter	-5.90	-6.75	-6.15	-1.78	-0.55
Log valuation	-4.21	-3.39	-1.90	-1.00	-2.42
Log valuation per square meter	-7.67	-8.35	-7.92	-4.02	-1.48
Estimated monthly subsidy of energy	9.69	10.51	10.06	9.33	6.92
Estimated monthly subsidy of piped water and sewerage	9.41	9.91	10.20	8.75	5.80
Estimated monthly subsidy of piped gas	11.74	13.76	12.77	11.98	8.06
Number of rooms	-9.93	-9.77	-7.07	-3.93	-4.60
Number of bathrooms	-2.71	-2.49	-2.88	-1.06	-4.53
House with Piped gas service	-4.35	-3.86	-1.65	-1.10	-2.89
House with telephone	-3.15	-3.06	-1.41	-1.58	-0.93
House with garden	0.38	1.23	0.48	0.71	-1.10
House with court yard	3.15	2.67	3.44	0.57	1.75
House with garage	-7.01	-6.86	-6.36	-3.66	-2.63
Parks in neighborhood	-6.97	-10.85	-9.06	-6.98	-3.72
The house has suffered because of a natural disaster	3.15	3.36	3.66	2.48	2.73
House in area vulnerable to natural disasters	2.52	3.16	4.75	4.18	3.73
Factories in neighborhood	-1.64	-1.35	1.79	0.84	0.11
Airport in neighborhood	1.88	-1.25	-0.93	0.00	0.00
Terminals of ground transportation in neighborhood	-0.79	-1.98	-0.63	1.95	1.81
House close to open sewers	-0.06	-0.99	1.02	-0.74	1.21
Plants of residual water treatment in neighborhood	0.69	0.71	0.00	0.00	0.00
Lines of hydrocarbon transportation in neighborhood	0.00	0.00	0.00	0.00	0.00
You feel safe in your neighborhood	-2.38	-2.26	-1.61	-0.78	-1.70
Toilet inside the house	-3.05	-2.57	-1.94	-0.83	-2.16
Daily supply of water	-2.88	-2.09	-2.07	-4.08	-3.95
Provision of water is inside the house	-1.56	-1.35	-0.50	-1.02	-1.18
The kitchen is a individual room	-2.40	-1.98	-3.15	-1.97	-1.41
House**	2.37	3.31	2.61	0.30	-1.06
Floor material is Carpet	0.04	-0.02	-2.30	-1.40	-0.06
Floor material is any of: Floor tile, vinyl, tablet, wood	-2.87	-2.35	-0.28	0.58	0.01
Floor material is any of: Coarse wood, table, plank	0.89	1.63	2.28	1.29	1.88
Floor material is any of: Cement, gravilla, earth, sand	7.82	6.52	4.23	3.17	1.99
House with Toilet connected to the public sewerage	-0.99	-0.09	-0.66	0.37	0.35
House with potable water service	-1.19	-0.19	0.44	-0.02	0.13
Number of infantile shelters by censal sector	-0.15	0.04	1.04	0.22	-1.29
Number of asylums by censal sector	3.42	0.17	-0.67	-2.23	-1.36
Number of prisons by censal sector	-1.75	-1.51	1.54	2.16	2.25
Number of convents by censal sector	-2.06	-1.09	-0.54	-3.28	0.37
Area of the land (squared meters)	3.46	4.12	4.75	2.52	0.15
Constructed area (squared meters)	0.93	2.26	4.77	3.84	1.56
Number of observation (full sample)	3,956	3,388	2,034	1,011	652
Number statisicaly different from zero	19	19	15	13	11
Total number of active controls	33	33	32	31	31
Percentage of active controls different from zero	58	58	47	42	35

T-statistics test whether the difference in means between the better and worse sides of the boundaries are equal. Only variables statistically significant in all regressions estimated with boundary dummies are included. * The square meters used are the sum of those of the land plus those of the construction. ** Dummy=1 if living in house (as opposed to an apartment, etc.). *** There are 18 frontiers that have on one side stratum 2 and on the other stratum 3, 10 with strata 1 and 2, 16 with strata 3 and 4, 6 with strata 4 and 5, and 4 with strata 5 and 6.

Annex 2. Local linear regression estimates for worse and better sides of the boundaries between all strata*



Biweight kernel and a bandwidth of 600 m., were used in the LLR regression. * Estimates at the boundary differ from those presented in annex 3 since these graphs are estimated with the lp_regress Stata command, which does not use sample weights, while estimates in annex 3 do.

Annex 3. Local regression estimates and t-statistics obtained when comparing means of characteristics between the better and worse sides of boundaries between all strata

Variable	Better Side		Worst Side		*t*-statistic[/1]
	E(·|Distance≈0)	Std. Err.	E(·|Distance≈0)	Std. Err.	
Logarithm of house valuation	12.105	0.062	12.117	0.047	-0.2
Logarithm of house valuation per square meter *	12.108	0.055	12.116	0.042	-0.1
Estimated monthly subsidy of energy	2,704	638	7,879	757	**-5.2**
Estimated monthly subsidy of piped water and sewerage	8,993	1,346	16,544	1,314	**-4.0**
Number of rooms	3.768	0.173	3.288	0.172	**2.0**
Number of bathrooms	1.644	0.087	1.467	0.081	1.5
House with piped gas service	0.674	0.043	0.579	0.065	1.2
House with telephone	0.923	0.035	0.918	0.036	0.1
House with garden	0.406	0.065	0.460	0.068	-0.6
House with court yard	0.024	0.014	0.048	0.028	-0.8
House with garage	0.310	0.052	0.182	0.046	1.8
Parks in neighborhood	0.135	0.030	0.042	0.030	**2.2**
The house has suffered because of a natural disaster	0.016	0.017	0.056	0.032	-1.1
House in area vulnerable to natural disasters	0.0003	0.015	0.061	0.037	-1.5
Factories in neighborhood	0.165	0.038	0.210	0.048	-0.7
Airport in neighborhood	0.007	0.003	0.003	0.002	1.0
Terminals of ground transportation in neighborhood	0.022	0.007	0.025	0.007	-0.3
House close to open sewers	0.046	0.031	0.041	0.039	0.1
You feel safe in your neighborhood	0.584	0.050	0.645	0.061	-0.8
Toilet inside the house	1.0	0.004	0.999	0.009	0.4
Daily supply of water	1.0	0.006	0.854	0.042	**3.6**
Provision of water is inside the house	1.0	0.005	0.997	0.008	0.8
The kitchen is a individual room	0.973	0.018	0.952	0.028	0.6
House**	0.481	0.058	0.406	0.061	0.9
Floor material is Carpet	0.123	0.031	0.109	0.030	0.3
Floor material is any of: Floor tile, vinyl, tablet, wood	0.682	0.049	0.783	0.050	-1.4
Floor material is any of: Coarse wood, table, plank	0.025	0.013	0.042	0.017	-0.8
Floor material is any of: Cement, gravilla, earth, sand	0.996	0.005	0.9999	0.0001	-0.7
House with Toilet connected to the public sewerage	1.0	0.004	1.0	0.002	-0.7
House with potable water service	0.040	0.027	0.026	0.028	0.3
Number of prisons by censal sector	0.006	0.002	0.015	0.004	-1.9
Number of infantile shelters by censal sector	0.084	0.024	0.033	0.019	1.7
Number of asylums by censal sector	0.225	0.046	0.109	0.033	**2.1**
Number of convents by censal sector	0.173	0.068	0.025	0.040	1.9
Area of the land (squared meters)	150.714	8.624	153.633	12.520	-0.2
Constructed area (squared meters)	105.251	8.077	90.451	7.291	1.4
Number statisticaly different from cero					4
Total number of active controls					32
Percentage different from cero out of all active controls					12.5

[1/] t-statistics tests whether the difference in LLR estimates evaluated close to the boundaries (distance ≈ 0) between the better and worse sides of the boundaries is different from cero. Only variables statistically significant in all regressions estimated with boundary dummies, and active at the boundaries with the chosen bandwidth, are included. Sample weights, biweight kernel and a bandwidth of 600 m., were used in the LLR regression. Bootstrap standard errors are obtained based on 100 replications with 100% sampling. * The square meters used in the sum of those of land plus those of construction. ** Dummy=1 if living in house (as opposed to an apartment, etc.).

Annex 4. House price model results: basic OLS regression*

Variable	Coefficient	*T*
Number of rooms	0.0182	4.9
Number of bathrooms	0.1071	15.9
House with piped gas service	0.0187	1.9
House with telephone	-0.0101	-0.6
House with garden	0.0193	2.2
House with court yard	0.0269	1.2
House with garage	0.0631	6.7
House with terrace	-0.0139	-1.4
Parks in neighborhood	0.0722	5.6
The house has suffered because of a natural disaster	0.0042	0.1
House in area vulnerable to natural disasters	-0.0415	-1.7
Factories in neighborhood	-0.0131	-1.1
Garbage collector in neighborhood	-0.0728	-2.6
Market places in neighborhood	0.0127	0.7
Airport in neighborhood	-0.0315	-1.3
Terminals of ground transportation in neighborhood	0.0470	2.2
House close to open sewers	-0.0556	-4.7
Plants of residual water treatment in neighborhood	0.2513	6.4
Lines of hydrocarbon transportation in neighborhood	0.1315	3.8
House close to high tension lines of electricity transmission	-0.0084	-0.3
You feel safe in your neighborhood	0.0121	1.5
Toilet inside the house	-0.0453	-0.9
Daily supply of water	0.0063	0.2
Provision of water is inside the house	-0.0062	-0.1
The kitchen is a individual room	0.1054	2.7
House**	-0.1301	-13.1
Walls material is any of: Brick, block, stone, polished wood	0.0254	0.6
Floor material is any of: Marmol, parque, lacquered wood	0.0049	0.2
Floor material is Carpet	0.0548	2.4
Floor material is any of: Floor tile, vinyl, tablet, wood	0.0136	0.7
Floor material is any of: Cement, gravilla, earth, sand	-0.0971	-4.1
House with Toilet connected to the public sewerage	0.2671	2.8
House with potable water service	0.0894	1.0
Number of infantile shelters by censal sector	-0.0148	-1.2
Number of asylums by censal sector	0.0153	1.86
Number of prisons by censal sector	0.0479	1.7
Number of convents by censal sector	0.0316	7.0
Stratum 2	0.2364	6.0
Stratum 3	0.6205	13.6

Stratum 4	0.9170	17.8
Stratum 5	1.1879	19.9
Stratum 6	1.4192	19.8
Area of the land (squared meters)	0.0010	5.4
Interaction variable Land*stratum2	0.0001	0.2
Interaction variable Land*stratum3	0.0015	6.5
Interaction variable Land*stratum4	0.0016	5.9
Interaction variable Land*stratum5	-0.0012	-2.8
Interaction variable Land*stratum6	-0.0008	-1.6
Constructed area (squared meters)	0.0039	21.2
Interaction variable Constructed area*stratum2	-0.0001	-0.4
Interaction variable Constructed area*stratum3	-0.0012	-6.3
Interaction variable Constructed area*stratum4	-0.0011	-4.2
Interaction variable Constructed area*stratum5	0.0009	2.7
Interaction variable Constructed area*stratum6	0.0014	4.5
Constant	15.6763	112
R^2	0.872	
Number of observations	5,292	

* Coefficients found from estimating equation (1) not shown in column A of table 7. Robust standard errors are estimated. Results are very similar when we also adjust them for clustering either at the boundary dummy level, or at each side of the boundary dummy level. Boundary dummies are not included, although Bogota´s neighborhood fixed effects (19) are.