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Stratification and Public Utility Services in Colombia: Subsidies to Households or Distortion of Housing Prices?

There is ample consensus about the desirability of subsidizing the consumption of public utility services because of the positive externalities that result when they are supplied and the high public costs generated by their absence. On that basis, most Latin American countries subsidize the supply of services and constantly try to improve their targeting systems while minimizing social losses associated with the subsidy schemes.

States in the region that allocate subsidies for residential public utility services (*servicios públicos domiciliarios,* or SPD) have always found the targeting and coverage of subsidies a source of controversy, debate, and criticism.[1] Among the ways used in the region to reach households with SPD subsidies are cross subsidy schemes, subsidies to supplying utilities, cash transfers, and so forth. Because of the variety of alternatives and the socioeconomic and cultural diversity of the countries of the region, no regional consensus exists on how subsidies should be targeted.

To the problem of lack of technical consensus can be added the difficulty of reforming the targeting systems derived from the complex political economy of subsidy policies in the region. That difficulty has become even greater

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

because some governments in the area have sought to consolidate their power base by subsidizing services to the poor.

A great deal of Colombian policy to improve social equity through public spending has focused on guaranteeing access to public utility services by the needy population. In fact, the targeting strategy used to provide SPD subsidies has become one of the criteria in the poverty and welfare measurement methodologies used to target most social public spending in the country.[2]

The country has several studies that have quantified SPD public expenditure amounts and determined the way that they are distributed among households of different income levels. However, there are no studies that quantify how much of the expenditure actually goes in the form of a subsidy into the pockets of the households living in subsidized housing units rather than being transferred or distorting factors such as relative housing prices. This paper presents a quantification of the incidence of SPD subsidies and contributions on housing prices, which it uses to estimate the net subsidy that the government transfers to households and actually stays in households' pockets.

We test the hypothesis that subsidies or contributions play a role in determining housing prices, so that we can identify some of the limitations of the current system of targeting subsidies for public utility services. To quantify the incidence of SPD subsidies on house prices, we estimate hedonic price equations, applying a regression discontinuity approach as our identification strategy. The empirical work is done with information from Bogotá. However, the institutional framework that governs the SPD subsidy targeting policy is the same countrywide, so we expect our findings to apply across Colombia's main cities.

We find that the estimated increment in house value due to subsidies is similar in magnitude to the present value of the flow of subsidies, discounted at reasonable market rates. We find comparable effects when we assess the effect of subsidies on leasing prices.

That finding leads us to conclude that in Colombia the goal of subsidy financing for the poor population through government spending on public utility services is not being achieved. The final effect of most of the government spending in this regard is the distortion of housing prices in different socioeconomic strata. While the public sector in Colombia distributes approximately 0.7 percent of GNP in so-called subsidies for public utility services each year,

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 to compute the index. The index is used to target more than 2 percent of GDP annually in supply and demand subsidies for health services.

the final effect of the distribution is to introduce a new feature, the subsidy, to houses in certain areas, which is then reflected in higher prices for those houses and the consequential distortion of relative housing prices.

We begin by presenting background information on Colombia, describing the country's targeting principles and the way that it has consolidated its targeting strategy. We then summarize the findings of related studies, describe our methodology and data, and give the results of empirical exercises. Finally, we present the conclusions.

Background

The targeting mechanisms used by the Colombian government since the second half of the twentieth century have changed very slowly, from simple ones based exclusively on consumption levels to more complex ones that combine consumption levels and characteristics of housing and neighborhoods. Until 1968, the country delivered subsidies for public utility services by means of a scheme of increasing block pricing (IBP), under which very low rates were charged for lower levels of consumption and higher rates were charged as consumption increased. This strategy lacked a reference unitary cost of services provided for the allocation of subsidies in addition to lacking a strong legal framework for implementation, and it was supported by direct government financing of the required infrastructure developments. Although the strategy was based on the assumption that better-off households would have higher consumption levels and therefore would be subject to higher rates, both rich and poor households showing below-average consumption benefited from the subsidy and ended up paying a rate that was below the cost of providing the service. Because utility companies could not achieve favorable cost recovery levels, they were unable to undertake infrastructure investment, network maintenance, and other needed activities, which inevitably caused a detriment in quality of the services provided and a low expansion of coverage. The scheme ended up characterized by high levels of inclusion of nonpoor households and exclusion of poor ones. In addition, its unfavorable fiscal balance led it to be considered a general subsidy scheme.[3]

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

3. See INECON (2006); Millán (2006).

new features to the targeting mechanisms: the definition of a basic consumption level, which would have the higher subsidized rates, and a different IBP structure contingent on housing appraisal.[4] By 1984 the JNT replaced the housing appraisal method with the socioeconomic strata system of the Department of National Statistics, which characterized housing units according to their characteristics and those of their neighborhoods. Still, under the new scheme the system recovered only up to 39 percent of the cost of supplying electricity.[5] But when the change took place, consumers staged public protests, illustrating the sensitivity of the subsidy issue in the country.

Seeking to improve the targeting mechanism, the JNT, along with public utility service providers, developed new socioeconomic stratification methodologies between 1984 and 1989.[6] Nonetheless, utility companies, which were mostly public, still exhibited poor cost recovery levels, low infrastructure investment, poor quality, and limited expansion of coverage.[7]

Under new legal guidelines included in the 1991 Colombian constitution and in law 142 and law 143 of 1994, a new conception of residential public utilities took shape in Colombia, focusing on the provision of an efficient supply of public 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 stratification methodology for municipalities to the Departamento Nacional de Planeación (DNP) (Department of National Planning) and assigned municipalities the responsibility for implementing it and updating it at least every five years. There would be six socioeconomic strata. Households living in strata one through three would be subsidized; those living in the fourth stratum would pay the marginal cost of services; and those living in strata five and six, along with the commercial and industrial sectors, would pay more than the cost of services (contributions). Subsidies would be granted only for consumption levels that were below the basic level.[9] Since the socioeconomic strata were created, they have been used to set differential rates for taxes and university tuition, to grant access to health subsidies, and so forth.

4. INECON (2006); Millán (2006).

5. See Millán (2006).

6. Millán (2006).

7. Between 1875 and 1930, the companies in Colombia supplying public utility services were private initiatives. Afterward, they were bought by the government, which by 1970 had become the main public utility services supplier in the country. See Meléndez (2004).

8. See DNP (2005).

9. Basic consumption levels were fixed at 200 kilowatt hours a month for electricity and twenty cubic meters a month for water.

Subsidies to public utility services are common in most Latin American countries. As shown in a World Bank report on water and sewerage services, in the case of piped water and sewerage, more than ten countries in the region have demand cross subsidies (Chile does not); some have direct subsidies; and most have investment subsidies.[10] Most important for our purposes is that most countries have geographically based targeting mechanisms; therefore our inferences are likely to apply to several of them.[11]

Literature Review

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

Table 1 presents the distribution of demand subsidies in Bogotá for piped water and electricity for 1970, 1992, and 2003.[12] A clear pattern emerges from the table: subsidies for electricity increased between 1970 and 1992 and decreased between 1992 and 2003. On the one hand, such reductions 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-sustaining system of providing public utility services. On the other hand, even though the incidence of subsidies relative to earnings is higher for the poorest households, historically the distribution of subsidies across deciles has been somewhat progressive, although on a very modest level.

Other studies have evaluated and proposed alternatives to targeting by socioeconomic stratification.[13] Meléndez proposed lowering the basic or sub-

10. ADERASA (2005). Among the countries reported to have cross subsidies for piped water and sewerage are Argentina, Bolivia, Brazil, Colombia, Costa Rica, Nicaragua, Panama, Paraguay, Peru, and Uruguay.

11. Among the countries reported to have geographic targeting mechanisms for piped water and sewerage subsidies are Argentina, Bolivia, Brazil (São Paulo), Colombia, Panama, and Peru. In addition, Paraguay and some cities in Brazil use household characteristics and socioeconomic conditions.

12. Estimates for Bogotá were not reported by Sánchez and Núñez (2000), Meléndez (2004), Fernández (2004), Lasso (2006), and INECON (2006).

13. Among the studies were Selowsky (1979), Vélez (1996), Sánchez and Núñez (2000), Meléndez (2004), Fernández (2004), Lasso (2006), Montenegro and Rivas (2005), and INECON (2006). Even the government did it in a recent policy document; see DNP (2005).

TABLE 1. Subsidy as a Percentage of Household Income in Bogotá

	Piped water				*Electricity*		
Decile	*1970*	*1973*	*1992*	*2003*	*1970*	*1992*	*2003*
1	n.a.	n.a.	3.0	3.6	0.2	5.7	3.6
2	n.a.		1.7	1.6	0.4	3.6	1.7
3	n.a.	2.1	1.3	1.3	0.3	2.6	1.4
4	0.9		1.1	0.9	0.3	2.3	1.0
5	0.7	1.2	0.8	0.8	0.3	1.7	0.8
6	0.5		0.6	0.6	0.2	1.5	0.6
7	0.4	0.3	0.5	0.4	0.2	1.3	0.4
8	0.2		0.3	0.3	0.0	0.9	0.3
9	–0.2	–0.6	0.1	0.1	–0.1	0.7	0.1
10	–0.8		0.1	0.0	–0.1	0.3	–0.1

Sources: 1970: Gutiérrez de Gómez (1975), quoted by Selowsky (1979); 1973: Lundquist (1973); 1992: Vélez (1996); 2003: authors' estimates based on ECV2003, see DANE (2003).

n.a. Not available.

sistence consumption levels for water and electricity (contingent on altitude in the case of electricity) and complementing stratification with the use of additional housing characteristics and level of education of the head of household to determine whether the household is eligible for subsidies, whether it should pay the marginal cost, or whether it should pay a fee.[14] Fernández assessed the accuracy of stratification in targeting the poor and estimated that for all public utility services the inclusion error increased from 53 percent to 58 percent between 1993 and 2003, highlighting the limitations of the system.[15] INECON also recognized significant deficiencies in targeting based only on stratification, mostly due to the broad heterogeneity of households residing in stratum 3. It mentioned the potential use of a Colombian proxy means test, the SISBEN, as a better option than stratification; nonetheless, it pointed out several drawbacks previously detected in the SISBEN that would require improvement of its current standards. Finally, it estimated the magnitude of gross demand subsidies to be 0.67 percent of GDP and contributions to be 0.41 per-

14. Meléndez (2004). In July 2004 the Colombian government mandated a gradual reduction in electricity basic consumption levels from 200 kilowatt hours in 2003 to 173 and 130 kilowatt hours in municipalities below and above an altitude of 1,000 meters, respectively, by 2007. See INECON (2006).

15. Fernández (2004). Inclusion error in the study is understood to be the fraction of the population receiving subsidies whose income is not among the lowest two-fifths of the income distribution.

cent of GDP, for a net demand subsidy of 0.26 percent of GDP.[16] In addition, the system received nearly 0.3 percent of GDP in supply subsidies.

Finally, DNP (2005) analyzed the nature and appropriateness of socioeconomic stratification as a targeting instrument.[17] The policy document highlighted several limitations and recommended reassessing stratification and redesigning its methodology. It also requested evaluation of new subsidy eligibility criteria for stratum 3 households, such as those in Colombia's 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 ultimately benefits the household or its owner, if different from the tenant, or simply distorts relative housing prices, benefiting no one.

Methodology

Although SPD demand subsidies can affect the value of multiple factors associated with them and also have bearings on the behavior of household members, this paper focuses on the incidence of these subsidies on housing prices and therefore on estimates of the subsidy that a household receives, net of such effects.

Our approach is based on the hypothesis that the housing market takes into account the subsidies or taxes that residents of certain dwellings will receive or pay. To clarify, let us compare two identical houses, one in stratum 4 and the other in stratum 3, that 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 therefore the cost to their occupants of residential public utility services: the one in stratum 3 would receive a subsidy; the one in stratum 4 would pay the total cost of the service. If the monthly subsidy received by the occupants of the stratum 3 house is S_i, then they would be willing to pay the net present value of the flow of subsidies expected to be received, net

16. INECON (2006). It includes gross subsidies to households in strata 1, 2, and 3 for piped water (0.15 percent), sewerage (0.08 percent), telecommunications (0.09 percent), and electricity (0.32 percent). The magnitude of demand subsidies estimated is consistent with Lasso (2006), which found a gross subsidy of 0.73 percent of GDP and contributions from strata 5 and 6 of 0.2 percent of GDP. INECON (2006) also reports contributions of about 0.2 percent of GDP from commerce and industry and another 0.2 percent of GDP from households in strata 5 and 6.

17. DNP (2005).

of their deadweight loss. That is the standard tax capitalization approach, developed by Oates.[18]

To find the incidence of SPD subsidy on housing prices, we estimate a hedonic price function. The estimated function describes the equilibrium that reveals the willingness of heterogeneous market agents to pay for each one of the characteristics that constitute the nonelastic housing supply.[19] The relationship that we estimate is the following:

$$\ln\left(p_{ij}\right) = \alpha + \mathbf{X}'_{ij}\beta + \gamma S_{ij} + u_{ij}, \tag{1}$$

where p_{ij} is the price of house i located at stratum j, the $\mathbf{X}_{ij}$ vector includes characteristics of the house and its neighborhood (at the census sector level), S_{ij} is the monthly SPD subsidy amount that might be obtained by living in the house, and u_{ij} is a random shock.[20] 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.[21] Nonetheless, the preci-

18. Oates (1969).

19. The estimated coefficients of that function represent the price paid by the marginal purchaser. See Rosen (1974).

20. Variables such as number of bathrooms and bedrooms, quality of piped water and sewer services, the presence of services in the home, and so forth are included for housing, and variables such as proximity to green zones, transportation terminals, and so forth are included for neighborhoods. A group of important variables included in the District Real Estate Appraisal—such as the built area and the lot area—and some strata dummy variable interactions with the built area and lot area are introduced to capture the differential effect of the dimensions of the units across the different strata. S_i is based on the amount paid for every public utility service as reported by households in the Living Standard Measurement Survey of 2003; the socioeconomic stratum is based on the utility bill charged; and the rate structure for each service is based on the rates in Bogotá for June 2003, which are published on the websites of public utility control agencies in Colombia. See Regulatory Commission for Electricity and Gas (Comisión Reguladora de Energía y Gas) (www.creg.gov.co/); Regulatory Commission for Water (Comisión Reguladora de Agua) (www.cra.gov.co/); Superintendent of Residential Public Utility Services (Superintendencia de Servicios Públicos Domiciliarios) (www.superservicios.gov.co/). The amount of subsidy received by each household for electricity, natural gas, piped water, and sewage service is included. The squares of the linear subsidies also are included in the regression to allow for detecting possible nonlinearities in the effect of subsidies on housing prices.

21. Among the studies that use this approach for Colombia are Castellar (1991), which estimated the implicit price of different attributes of a peasant farm, and Carriazo (1999), which performed hedonic regressions for Bogotá's housing market. Lasso (2006) estimated a similar equation in which the author aimed to determine the incidence of SPD subsidies on house rents in Colombia. International literature on hedonic prices and their methodological approaches can be found in Castellar (1991) and Cheshire and Mills (1999).

sion of the results depends on whether one includes all relevant information associated with housing prices. As observed in figure 1, there is significant variation in subsidy amounts within each socioeconomic stratum, which could be explained by the heterogeneity in within-stratum SPD demand due to the characteristics of both dwellings and their inhabitants. In addition, we exploit subsidy variations explained by the differences in SPD increasing block pricing encountered by housing on both sides of the strata borderlines.

If the changes in SPD subsidies are mainly associated with changes in a household's socioeconomic stratum, then it is important to control for the characteristics that determine the stratum for each house, which are only partially observable. In addition, the characteristics that determine the stratum for a house can differ, and they can affect the appraisal of the house in different ways. For example, one set of houses could be in stratum 6 because of the houses' luxurious characteristics, while another set could be in the same stratum because the houses have a better access to public goods, even if they are not as luxurious. Omitting that information could potentially bias the results from equation 1.

To overcome such difficulties, our approach begins by taking advantage of the way in which 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 have similar characteristics. It is important to note that despite stratification, the number of strata is too small to allow all houses in each city to be clustered in homogeneous groups, so that within the same socioeconomic stratum, differences in characteristics of houses within the same stratum become significant.

That becomes clear when the case of Bogotá is analyzed. The city has more than 40,000 blocks of houses grouped in six strata for the purpose of subsidy targeting, and each stratum contains an average of 7,000 blocks. Therefore it is hard to make the case that all housing units in Bogotá are highly homogeneous within strata, and that is also true for any other city in the country.

However, under the socioeconomic stratification system, we would expect the differences between houses on both sides of the borders that divide strata to be more subtle the closer the houses are to the nearest boundary. Therefore comparing houses close to the border on both sides will control for unobservable characteristics of the houses and their neighborhoods. If, in addition, it is possible to differentiate houses in the same stratum but in different sectors of the city (say, stratum 2 houses in the center of the city versus stratum 2 houses in the south), it is also possible to control for unobservable differences, such as the ones associated with the supply of public goods in different parts of the city. To account for these factors, we estimate the following model:

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

where $\mathbf{K}_b$ represents a vector of boundary dummies. These variables are such that every house is associated with the closest borderline between its own stratum and its neighboring stratum.

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 equation 1, and the subsidies. On the other hand, comparing different sets of houses according to their distance from their respective boundaries would correct potential biases—coming mostly from comparing noncomparable households—as we take houses closer to their closest boundaries, but it would do so in an unpredictable way.

Our methodology therefore is based on the following assumptions:

— Subsidies change discontinuously at the boundaries.
— Observable and unobservable characteristics of houses change continuously at the boundaries.
— The effect of public utility subsidies on house prices is continuous at the boundaries.
— The amount of subsidy is independent of its effect on house prices at the boundaries, after one controls for the side of the boundary.[22]

Appendixes A-1, A-2, A-3 present evidence that differences in means of the characteristics of houses on opposite sides of a boundary become statistically insignificant for several of the control variables the closer the houses are to the boundary. The differences in means are statistically significant for 58 percent of the control variables for houses that are located an average of 750 meters from the boundary, whereas they are statistically significant for only 42 percent of control variables for houses that are located 150 meters from the boundary.

To provide further evidence, we split the sample into households located on the better and worse sides of the boundaries and compute local linear regres-

22. The first, second, and third assumptions are known as the standard regression discontinuity (RD) assumptions, the continuity of characteristics and treatment effect, and conditional independence assumptions.

sion (LLR) estimates of all variables for each sample.[23] Appendix A-2 illustrates the results for energy and water subsidies and for some control variables, including whether the kitchen is an individual room, the number of bathrooms, whether the dwelling is a house, and whether the house has potable water service. Although the control variables shown in the figures in appendix A-2 seem to register a discontinuity around the boundaries, appendix A-3 shows that none of them actually does. Appendixes A-1 to A-3 present evidence that strongly supports the first and second assumptions listed above. First, they show how differences in LLR estimates of energy and water subsidies, evaluated for houses near the boundaries, are statistically significant across boundaries. Second, they show that as we move closer to the boundaries, to a point right next to them, differences in only 12.5 percent of the control variables (instead of the 42 percent obtained at 150 meters from the boundary, in appendix A-1) remain statistically significant across boundaries, providing additional evidence that as we move closer to the boundaries, differences across boundaries in housing units and their neighborhoods diminish.[24]

Errors in Stratum Measurement

The methodology used to identify the effects of SPD 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 it.

In the Encuesta de Calidad de Vida 2003 (ECV2003) (Living Standards Measurement Survey) conducted by the Departamento Administrativo Nacional de Estadística (DANE) (National Administrative Department of Statis-

23. 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 a 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 estimate $E[Y_i \mid Pr(D_j)]$. 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, that we are using to select the other houses j to get our estimate) of 300 meters. (Using other bandwidths we obtained similar results.) An LLR estimate is better than the more traditional kernel regression estimate 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); Heckman and others (1998).

24. 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 appendixes A-1 and A-3 that when we compare houses closer to the boundaries, the difference not only decreases but also changes its sign in the expected way.

tics), each household was asked what stratum the public utility company used to determine the household's billing for electricity service. In principle, that information should be taken directly from the electricity bill provided by the member of the household answering the survey. However, in some circumstances, the stratum written down by the interviewer did not match the household's actual stratum, not to mention the water and sewerage stratum, which was not asked for in the survey and might have differed from the one for electricity, even for the same house. In some cases, the electricity bill was not available at the time of the survey. The surveyed individual then might have reported not knowing what the stratum was—and the interviewer would have recorded it as unknown—or the individual might have reported an incorrect stratum.

Also, as foreseen by DANE, when the electricity bills in some cities did not specify the stratum but reported the qualitative residential category—ranging from "low-low" to "high"—the interviewer translated those categories into strata.[25] In some cases a small business or cottage industry operated within the house, and because of that, commercial or industrial rates were charged. The interviewer then had to assign the stratum reported most frequently for houses in the same housing segment in which the house was located.[26]

In the case of condominiums or apartment buildings, where the survey was answered by several households, sometimes an interviewed household did not provide information about the electricity stratum or about how many times a week the garbage was collected. The interviewer then supplied the information from the responses of other households in the same condominium or building.[27]

As mentioned, the stratum of housing units in our sample is based on ECV2003 data and also on information collected from Bogotá's Administrative Department for District Real Estate Appraisal (DACD, for its acronym in Spanish). However, the stratum obtained from the DACD information might include measurement error as well, since the data are available only for 2000, three years before the ECV2003 was collected. The stratum of some households therefore could have been changed before the survey.

25. DANE (2003). The conversion is based on the following convention: low-low as stratum 1; low, stratum 2; low-middle, stratum 3; middle, stratum 4; middle-high, stratum 5; and high as stratum 6.

26. A housing segment is composed of a set of ten to eleven houses on the same block.

27. In addition, surveyors are advised to take into account that the stratum can change from one house to another on the same block. However, the DACD claims that the stratification is defined for all the houses on the same block and that only in exceptional cases is any house on that block classified in a different stratum.

TABLE 2. Number of Houses per Stratum in Bogotá, 2003[a]

		Stratum given by those 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							

Sources: Encuesta de Calidad de Vida 2003 (ECV2003, or Living Standards Measurement Survey of 2003); District Real Estate Appraisal of the Administrative Department for the District Cadastre of Bogotá (to be referred to as DACD), data collected in 2000 (see text for details).

a. Numbers in bold represent matches in stratum identification between ECV2003 and DACD. Stratum 0 represents nonresidential stratum, that is, commercial and industrial sectors.

Table 2 shows the inconsistencies that exist between the two housing stratum measurements. About 10 percent of the households in the ECV2003 gave a stratum that does not match the official DACD stratification. These cases appear more frequently in the vicinity of borders between strata, and measurement errors are frequent inside strata as well.

To correct measurement error, the DACD stratum is used for the instrumentation of the ECV2003 stratum. The exercise assumes that the ECV2003 stratum, $E^{ECV2003}$, and the DACD stratum, E^{DACD}, are based on

$$E_i^{ECV2003} = E_i + \varepsilon_i \quad \text{and} \quad E_i^{DACD} = E_i + \eta_i, \tag{3}$$

where E_i is the actual stratum for house i and ε_i and η_i represent measurement errors.[28]

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

$$E_i^{ECV2003} = f\left(\alpha + \mathbf{X}_i'\beta_{1i} + E_i^{DACD}\beta_{2i} + v_i\right). \tag{4}$$

28. Since the sources for our stratum, the ECV2003 and DACD, are completely independent, the key assumption—that η_i and ε_i are independent and independent from E_i and u_{ijb}—is expected to hold in this case.

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

Data

We use data that combine information for the city of Bogotá from three sources: the ECV2003, which provides information about households, their dwellings, and neighborhoods; Bogotá's Administrative Department of District Real Estate Appraisal, from which we obtained the socioeconomic stratification and real estate appraisal of Bogotá's housing; and the 1993 population census, from which we estimated the surrounding variables for Bogotá at the census sector level.[29]

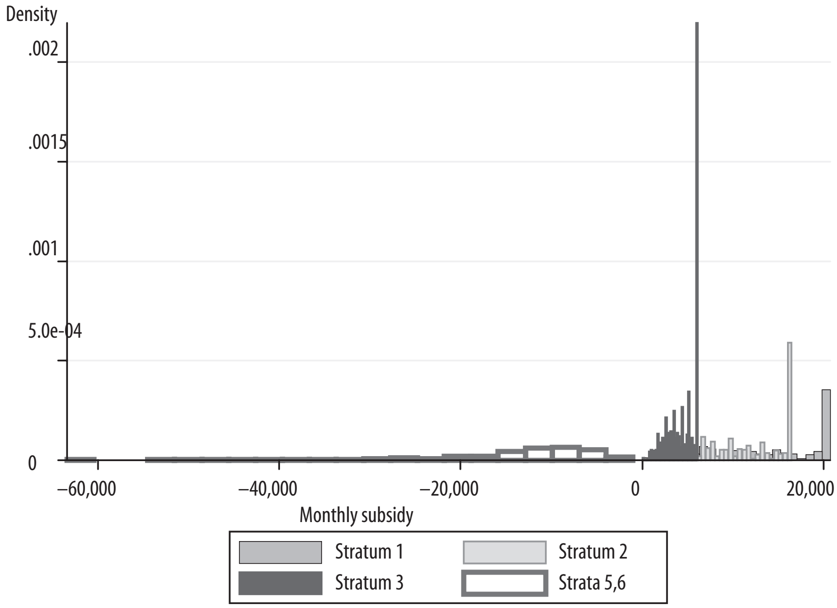
The fixed effects with which the houses are associated allow us to control for the presence of mass transportation systems (not observable in the survey). The comparison of houses within boundaries allows us to control for the unobservable variables of the neighborhood that determine the stratum classification and are not available as control variables. When estimating equation 2, we chose only households at a certain distance from the boundary of the stratum to which they belong, with a distance variable defined as the distance from each house to the nearest house located on the other side of the stratum boundary.

That way—and under the assumption that border location is relatively arbitrary given the large number of blocks stratified into only six groups—the specification used in equation 2 is consistent with the assumptions on which regression discontinuity design (RDD) is based, under which houses around a cutoff point (in this case, the boundary between two socioeconomic strata) are usually compared, and the only difference is that houses located on one side are subject to an intervention (in this case, subsidized SPD rates) and the ones on the other side are not.[30]

29. Bogotá is divided into more than 600 census sectors.

30. Black (1999) uses a similar approach to estimate willingness to pay for education quality. Other RDD applications include Van der Klaauw (2002) and Hahn, Todd, and Van der Klaauw (1999; 2001). Even though there are no similar RDD applications for Colombia, some works take into account the spatial dimension in special house hedonic price models. Goyeneche and others (2003) use the spatial dimension to examine the impact of erosion on land prices, detecting the presence of spatial autocorrelation, as does Morales (2005).

FIGURE 1. Monthly Electricity Subsidy Distribution per Socioeconomic Stratum in Bogotá, 2003[a]



Source: ECV 2003. See table 2.
a.–Subsidy amounts are in Colombian pesos.

Estimation of SPD Subsidy

Equation 2 assumes occupants of each house receive a monthly subsidy, S_i, which can be predicted by market agents on the basis of household characteristics and particularly of the socioeconomic stratum where the house is located. 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 shown in the figure, a house located in stratum 1, 2, or 3 will almost surely receive a subsidy of up to COP$20,000 (Colombian pesos) per month, while one in stratum 4 would pay the full cost of service, thus neither receiving a subsidy nor paying a fee. A household in stratum 5 or 6 would certainly pay a fee, in theory unlimited but in practice observed to average COP$12,000 a month. Agents in the market observe attributes of the house and its neighborhood in addition to the stratum—such as the total area of the house, number of bedrooms, and so forth—on which they base their estimates of the potential SPD subsidy for the house.

While water and sewerage services also have three rate blocks that define the so-called subsistence, complementary, and sumptuary consumptions, services such as electricity and natural gas have only two blocks.[31] Figure 2 describes the bill that households in different strata have to pay for each service according to their consumption level and gives the 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 consumption; stratum 4 pays a rate equal to the cost; and strata 5 and 6 pay a rate above the cost.[32]

Tables 3 and 4 show that for electricity and water services, most of the households are in the subsistence consumption interval. For electricity, 62 percent of all households are in that interval, with 78 percent of households (the highest share among the six strata) in stratum 1 (the lowest socioeconomic stratum) and 21 percent (the lowest share among the six) in stratum 6. For piped water, 76 percent of all households are in the subsistence interval, with shares of more than 70 percent for households in strata 1 to 5 and less than 60 percent for those in stratum 6. According to these figures, both subsistence consumption levels are high; nonetheless, the one for water is considerably higher than that for electricity.

Descriptive Statistics and Results

Appendix A-4 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 allows us to estimate all

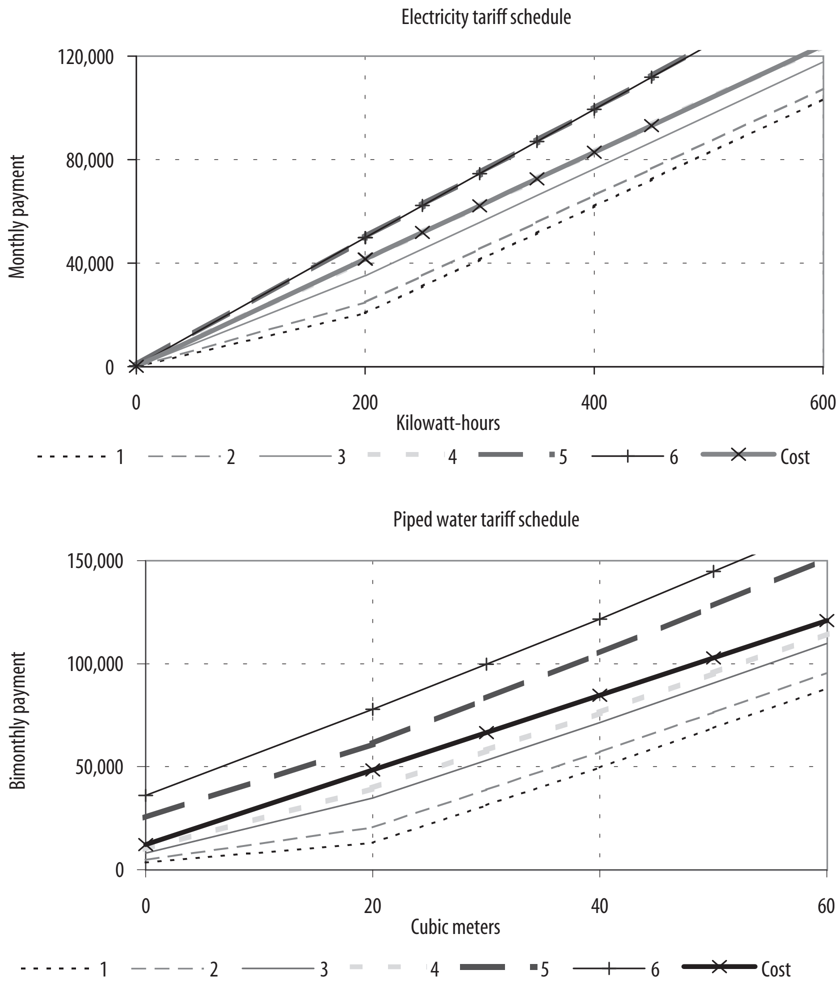
31. Subsistence consumption for electricity is 200 kilowatts per hour, while that for piped water and sewerage is twenty cubic meters. Any consumption below those quantities has a marginal price lower than its cost for households located in the poorest strata.

32. The amount of the bill is calculated according to

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

where V corresponds to the bill amount for a house located in stratum e; $v_0^{(e)}$ is the fixed charge collected from houses located in stratum 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 is the interval where Q is located.

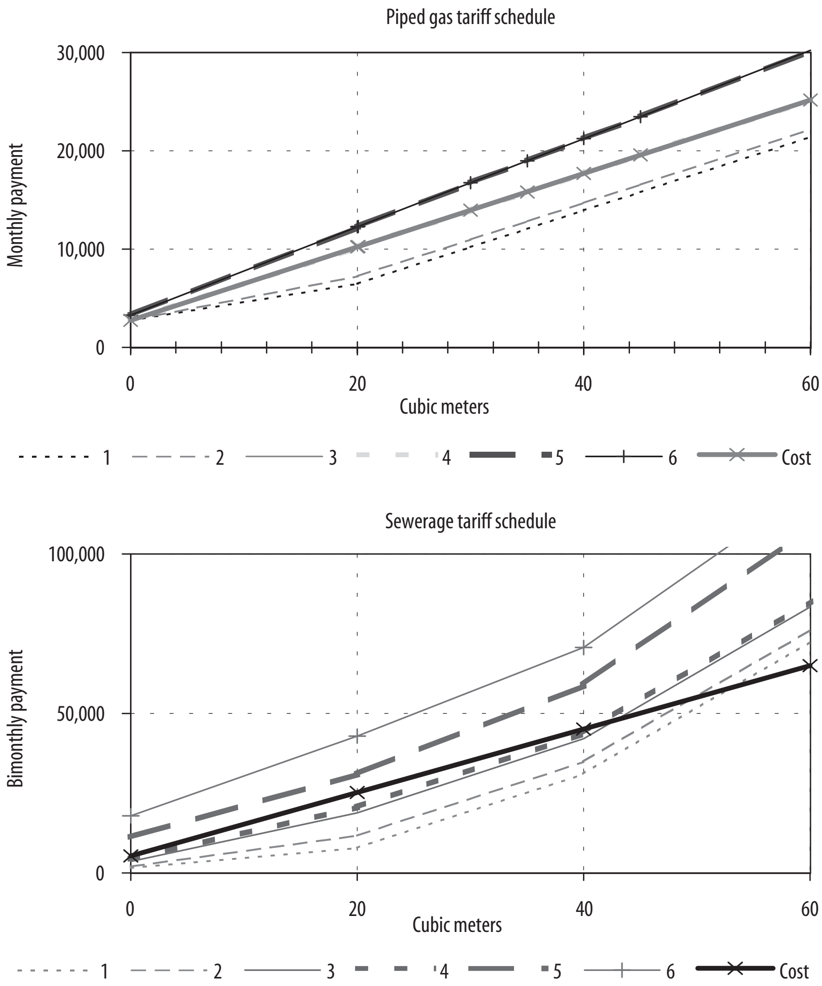
FIGURE 2. Schedules of Rates for Public Utility Services in Bogotá, by Stratum, June 2003[a]



Source: ECV 2003. See table 2.

a. Payments are expressed in Colombian pesos.

FIGURE 2. Schedules of Rates for Public Utility Services in Bogotá, by Stratum, June 2003[a] (*continued*)



Source: ECV 2003. See table 2.

a. Payments are expressed in Colombian pesos.

TABLE 3. Households, by Electricity Consumption, Bogotá, 2003

	Stratum						
Kilowatt-hours	*1*	*2*	*3*	*4*	*5*	*6*	*Total*
Number of houses by electricity consumption in each stratum							
Less than or equal to 200	75,108	381,010	456,701	87,809	26,981	12,000	1,039,609
Greater than 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	1,670,18
Percentage of houses by electricity consumption in each stratum							
Less than or equal to 200	77.75	71.21	63.34	47.93	34.90	21.06	62.25
Greater than 200	22.24	28.79	36.66	52.06	65.10	78.93	37.75
Total	100	100	100	100	100	100	100.00
Percentage of houses by electricity consumption per stratum across all strata							
Less than or equal to 200	7.22	36.65	43.93	8.45	2.60	1.15	100
Greater than 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

Source: ECV2003 (see table 2).

subsidies (for electricity, gas, and piped water and sewerage) for only 8,277 households. On the other hand, the DACD information allows us to obtain the real estate appraisal values for 8,879 households; when merged with the information for the ECV2003 households, these give a total of 5,759 households with complete information.

It can be inferred from appendix A-4 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 a higher proportion in strata 3, 4, and 5. It also includes houses with higher real estate appraisals per square meter, houses with smaller lots and built areas, and a larger proportion of houses than of other housing units. It includes houses with more bedrooms and bathrooms and a higher probability of having gas and telephone service, a garage, and a terrace—in general, better amenities.

Table 5 shows housing prices and utility subsidy amounts by stratum.[33] These data reveal the need to control in our empirical exercise for characteristics on which the socioeconomic strata are based to minimize the possibility of obtaining biased coefficients.

33. The price per square meter is defined as the house price divided by the average of square meters of terrain and square meters of built area.

TABLE 4. Households, by Piped Water Consumption, Bogotá, 2003

	Stratum						
Cubic meters	*1*	*2*	*3*	*4*	*5*	*6*	*Total*
Number of houses by piped water consumption in each stratum							
Less than or equal to 20	52,955	352,725	515,297	123,501	51,145	27,440	1,123,061
20 less than 40	17,636	99,118	126,268	43,393	18,657	11,749	316,822
Greater than 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
Percentage of houses by piped water consumption in each stratum							
Less than or equal to 20	74.43	77.04	78.11	71.34	70.27	59.36	75.84
20 less than 40	24.79	21.65	19.14	25.07	25.63	25.42	21.40
Greater than 40	0.79	1.30	2.75	3.59	4.09	15.22	2.76
Total	100	100	100	100	100	100	100
Percentage of houses by piped water consumption per stratum across all strata							
Less than or equal to 20	4.72	31.41	45.88	11.00	4.55	2.44	100
20 less than 40	5.57	31.29	39.85	13.70	5.89	3.71	100
Greater than 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

Source: ECV2003 (see table 2).

TABLE 5. House Prices per Square Meter and Subsidies in Bogotá, by Socioeconomic Stratum, 2003[a]

				Subsidies		
Stratum	*Number of observations*	*Housing price per square meter*	*Housing price*	*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

Sources: Housing price per square meter: DACD; Subsidies: ECV2003 (see table 2).

a. Housing prices and subsidies are in Colombian pesos. Negative figures represent contributions.

To estimate equation 2, we constructed fifty-six boundary dummies, each of which contains between 1.3 percent and 7.2 percent of the households with complete information. In constructing these variables, we used only houses associated with boundaries between strata that included no natural barriers and (since we sought to smooth changes in characteristics across boundaries) only areas that did not have a large stretch of land (parks, industrial zones, and so forth) separating the strata from their boundaries. Next, we show the results obtained when equations 1 and 2 are estimated with the logarithm of housing prices.

Results

Results of estimating by ordinary least squares (OLS) equations 1 and 2 for the logarithm of house prices are shown in table 6.[34] The top panel shows estimates of equation 1 in the first column, and the other columns show estimates of equation 2, which include boundary dummies and houses closer to the borders.[35] The top panel presents the results for each subsidy included and its square term, and the one at the bottom shows the estimates when we used the total amount of subsidy and its square rather than each of its parts. Table 7 shows the same set of results after each 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 the quadratic term of EE and total subsidy. The linear and quadratic term coefficients of EE subsidy obtained by OLS without controlling for boundary dummies and using the entire sample (A in table 6) are slightly overestimated by about 1 percent and 7 percent respectively with respect to their value when we control for boundary dummies (B in table 6). As we compare houses closer and closer to the boundary, for the households located 250 meters from the boundaries (C in table 6; our RD estimates were obtained without correcting for measurement error), the linear and quadratic estimates increase up to 48 percent and 8 percent respectively with respect to the estimates found when we use the whole sample and control for boundary dummies. The linear OLS coefficient of AA

34. The real estate appraisal value is used as the house price, which is the price of the house estimated by the government and the basis for local property taxes. In ECV2003, property owners were asked about the value of their house; however, their estimates were basically subjective.

35. The reported distances in meters (4,500, 1,500, 1,000, 800, 700, 600, 500, and 400) are the minimum distances 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 be approximately half the distance reported in the table (that is, 2,250, 750, 500, 400, 350, 300, 250, and 200).

TABLE 6. House Price Model, OLS[a]

	Disaggregated subsidies									
	Without boundaries, equation 1		*With boundaries, equation 2*							
	Whole sample (A)		*Whole sample (B)*		*4,500m*		*1,500m*		*1,000m*	
	N = *5,292*	R^2 = *0.8715*	N = *5,292*	R^2 = *0.8823*	N = *4,428*	R^2 = *0.8997*	N = *3,935*	R^2 = *0.8986*	N = *3,379*	R^2 = *0.9011*
Variable	*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 squared	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 squared	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 squared	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
	With boundaries, equation 2									
	900m		*700m*		*600m*		*500m (C)*		*400m*	
	N = *3,140*	R^2 = *0.9038*	N = *2,679*	R^2 = *0.8986*	N = *2,400*	R^2 = *0.9007*	N = *2,085*	R^2 = *0.9049*	N = *1,647*	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 squared	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 squared	−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 squared	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

	Without boundaries, equation 1		*With boundaries, equation 2*							
	Whole sample (A)		*Whole sample (B)*		*4,500m*		*1,500m*		*1,000m*	
	N = *5,292*	R^2 = *0.8713*	N = *5,292*	R^2 = *0.8821*	N = *4,341*	R^2 = *0.9012*	N = *3,935*	R^2 = *0.8983*	N = *3,379*	R^2 = *0.9008*
Variable	*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 squared	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
	With boundaries, equation 2									
	900m		*700m*		*600m*		*500m (C)*		*400m*	
	N = *3,140*	R^2 = *0.9035*	N = *2,679*	R^2 = *0.8982*	N = *2,400*	R^2 = *0.9003*	N = *2,085*	R^2 = *0.9044*	N = *1,647*	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 squared	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

Source: Authors' calculations based on ECV2003 (see table 2).

OLS = ordinary least squares; m = meters; std. err. = standard error.

a. The dependent variable is the logarithm of house prices. Results are from estimating equations 1 and 2 for the dependent variable by ordinary least squares. 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.

subsidies obtained without controlling for boundary dummies (A in table 6) is overestimated as well, since it falls by 14 percent when we include the boundary dummies (B in table 6) but increases again 3 percent when we analyze only households 250 meters from the boundary (C in table 6).[36] The OLS coefficients for the total amount of subsidies, without controlling for boundary dummies (A in table 6), are 9 percent larger than their counterparts with boundary dummies for households 250 meters from their boundaries (C in table 6).

Once the model is corrected for measurement error and the results are compared with the ones obtained when we estimated the model by OLS, we find that for houses located approximately 250 meters from the border (C in tables 6 and 8), the linear coefficient of the EE subsidy decreases by 8 percent and the one for the AA subsidy increases by 14 percent, while the quadratic coefficient of the EE subsidy decreases 60 percent and that of the AA subsidy increases by 8 percent.[37] Finally, when we compare the estimate that corrects for measurement error and controls for boundary dummies for the sample of houses up to 250 meters from the border (C in table 7; our RD estimate obtained after correcting for measurement error) with the estimate obtained by omitting the boundary dummies and using the whole sample (A in table 7), we find that the linear coefficient of EE increases 200 percent while that of AA decreases 20 percent. Nonetheless, only for distances 400 meters from the boundaries (800 meters in the table) is the linear EE coefficient statistically different from zero, while that is always the case for the AA subsidy.[38]

In sum, the final estimate of the linear EE coefficient (C in table 7) is 35 percent larger that the estimate obtained by OLS using the whole sample (A in table 6), since the OLS estimate is underestimated because the sample was not restricted to the one closest to the boundaries and overestimated for measurement error. But the final estimate of the linear AA coefficient (C in table 7) is similar to the estimate we obtained by OLS using the whole sample (A in table 6). Nonetheless, the OLS estimate is overestimated because the boundary

36. Nonetheless, neither of the estimates found with equation 2 are statistically different from those found with equation 1.

37. In this case, these pairs of differences are not statistically different from zero.

38. Again, after we correct for measurement error, neither of the estimates found with equation 2 for the whole sample or for houses 500 meters from the boundary are statistically different from those found with equation 1. Significance of the coefficients is robust to regressions run correcting for clustering when households in each stratum (that is, on 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 7) on the electricity subsidy is 2.3, while that of our RD estimate on the water subsidy is 1.9. In the second case, the figures are 2.3 and 2.2 for our RD coefficients for EE and AA respectively.

TABLE 7. House Price Model, IV[a]

	Disaggregated subsidies									
	Without boundaries, equation (1)		*With boundaries, equation (2)*							
	All sample (A)		*All sample (B)*		*4500m*		*1500m*		*1000m*	
	N = *5,155*	$R^2 = 0.8741$	N = *5,155*	$R^2 = 0.8837$	N = *4,343*	$R^2 = 0.9009$	N = *3,850*	$R^2 = 0.8992$	N = *3,294*	$R^2 = 0.9013$
Variable	*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 squared	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 squared	−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 squared	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
	With boundaries, equation (2)									
	900m		*700m*		*600m*		*500m (C)*		*400m*	
	N = *2,840*	$R^2 = 0.9017$	N = *2,597*	$R^2 = 0.9012$	N = *2,318*	$R^2 = 0.902$	N = *2,002*	$R^2 = 0.9057$	N = *1,569*	$R^2 = 0.9044$
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 squared	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 squared	−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 squared	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

(continued)

TABLE 7. House Price Model, IV[a] *(continued)*

	Aggregated subsidies									
	Without boundaries, equation (1)		*With boundaries, equation (2)*							
	All sample (A)		*All sample (B)*		*4500m*		*1500m*		*1000m*	
	N = *5,153*	R^2 = *0.874*	N = *5,153*	R^2 = *0.8836*	N = *3,848*	R^2 = *0.8992*	N = *3,848*	R^2 = *0.8992*	N = *3,292*	R^2 = *0.9011*
Variable	*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 squared	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
	With boundaries, equation (2)									
	900m		*700m*		*600m*		*500m (C)*		*400m*	
	N = *2,838*	R^2 = *0.9014*	N = *2,595*	R^2 = *0.9008*	N = *2,317*	R^2 = *0.9022*	N = *2,002*	R^2 = *0.9054*	N = *1,569*	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 squared	–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

Source: Authors' calculations based on ECV2003 (see table 2).

IV = instrumental variable; m = meters; std. err. = standard error.

a. The dependent variable is the logarithm of house prices. Table shows results after each stratum was instrumented to correct for measurement error. 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.

dummies were not included, underestimated because the sample was not restricted to the one closest to the boundaries, and underestimated because of measurement error.[39] In short, the inclusion of boundary fixed effects, the comparison of closer houses, and the correction for measurement error all play a role in getting us closer to obtaining unbiased estimators of the effect of SPD subsidies on housing prices.[40]

Table 8 shows the necessary information for the calculation of the elasticity of house prices per square meter with respect to each of the subsidies, using the coefficients obtained in columns A, B, and C of tables 6 and 8. Differences in the estimated elasticities include differences in both the linear and quadratic coefficients of tables 6 and 8. Here again, although our RD estimates do not differ significantly from the basic estimates obtained by OLS, including noncomparable households, omitting variables, and not correcting for measurement error are all effects that bias the estimates in counterbalancing ways that are concealed when the total changes for the estimates are compared. As shown in table 8, our RD estimates are very similar for EE (2.97 percent) and AA (2.95 percent).

To estimate the subsidy received by households, net of its effect on housing prices, we present in table 9 estimates of the current net present value (NPV) for all subsidies and contributions, discounted at 10 percent and 15 percent annual real interest rates, and the changes that a 100 percent variation in subsidies implies on house prices based on the elasticity estimated in table 8, Δvaluation.[41]

39. The other estimates found when equation 1 is estimated (column A in table 6) are included in appendix A-5. As shown, the value of houses increases when they have better characteristics, such as a greater number of rooms and bathrooms, piped gas, a garden, a garage, a separate kitchen, better floor materials, and toilets connected to the public sewage system; when there are parks in the neighborhood and public services such as ground transportation, garbage collection, and potable water; when the house is located in a better stratum; and when the lot or the built area are larger.

40. Nonetheless, the coefficients obtained with equation 2 for the whole sample or for houses 500 meters from the boundary and those obtained with equation 1 are not statistically different.

41. A 100 percent subsidy variation represents approximately 75, 80, and 40 percent of the standard deviations of EE, AA, and piped gas subsidies, respectively. Yet households in the survey report mortgage payments of around 1.05 percent of their house appraisal, which is close to the 1.09 percent that they would have to pay as an annuity for a mortgage of fifteen years (the standard term in Colombia) at a 10 percent annual interest rate. Currently, rates on mortgage loans have reached historical lows—inflation (always more than 5 percent) plus 7 percent. Clearly our estimates are expected values, since there is uncertainty on several variables, among them interest rates, opportunity cost of households, and subsidies themselves. Finally, we estimate the net present value of subsidies as the NPV of the perpetuity of the mean subsidy reported in table 7 at the reference interest rate. The NPV of the electricity subsidy is $8{,}108 / [(1 + r)^{1/N} - 1]$, where r is 0.10 or 0.15 and N is 12.

TABLE 8. Implicit Elasticities between Subsidy and House Prices[a]

				Elasticities							
				OLS			IV				
				Whole sample		500m	Whole sample		**500m**	(6) – (1)	
Variable	Average subsidy[b]	Average contribution[c]	Average subsidy (all households)[d]	Without BD (1)	With BD (2)	With BD (3)	Without BD (4)	With BD (5)	**With BD (6)**	Diff.	t
Energy (EE)	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 (AA)	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**		

Source: Authors' calculations based on sources for table 2.

IV = instrumental variables; OLS = ordinary least squares; BD = boundaries; Diff. = difference.

a. Results are obtained with the sample located at an average of 250 meters (m) from the border (500m between each house and to the closest one from another stratum on the other side of the boundary), and correcting for measurement error. Average subsidies and contributions are in Colombian pesos. Robust standard errors are in parentheses.

b. Each line includes only those households that reported the amount paid last month for their consumption and received subsidies for that respective service (EE, AA, or both).

c. Each line includes only those households that reported the amount paid last month for their consumption and paid contributions for that respective service (EE, AA, or both).

d. Each line includes all households that reported the amount paid last month for their consumption, regardless of whether they received subsidies or paid contributions for any service (EE and AA).

TABLE 9. Comparison of the Net Present Value of Subsidies with Their Incidence on Housing Prices[a]

Table of average results for annual discount rate of 10 percent							
		NPV		*Δvaluation*		*Δvaluation per NPV*	
Variable	*Elasticity*	*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 percent							
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

Source: Authors' calculations.

NPV = net present value.

a. 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 meters (m) from the border (500m between each house and to the closest one from another stratum on the other side of the boundary), and correcting for measurement error. The change in house valuation, "Δvaluation," is generated by a 100 percent change in subsidy.

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

Finally, table 10 illustrates not only how the net subsidy becomes in fact 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 percent annual real interest rate is a positive subsidy for the poorest households found. However, that is the population that is expected to have a higher opportunity cost of money, and so it also would be expected to be more likely to discount the flow of subsidies at higher rates. There are important reductions in AA subsidies due to housing capitalization in the case of AA, in which only the poorest 20 percent of the population end up receiving a somewhat relevant amount.

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

TABLE 10. Distribution of DPS Subsidies Net of Their Incidence on House Value in Bogotá, 2003[a]

			Energy (EE)			
			Discount rate = 0.10		*Discount rate = 0.15*	
Decile	*Monthly amount of subsidies*	*Subsidy as percentage of income*	*Amount of net subsidy*	*Net subsidy as percentage of income*	*Amount of net subsidy*	*Net subsidy as percentage 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)			
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

Source: Authors' calculations.

a. Results are obtained with the sample located at an average 250 meters (m) from the border (500m between each house and to the closest one from another stratum on the other side of the boundary), and correcting for measurement error.

b. Amounts of subsidies are expressed in Colombian pesos.

Results for Rents

The ECV2003 asks households that pay rent to report their monthly payment. In addition, it asks those who live in their own house for the amount of rent that they believe the house would generate if it were rented. Using as the dependent variable the logarithm of the rents reported in both instances, we repeat the previous exercise. 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, which we obtained in a way similar to the way we obtained house valuations, 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 factors necessary to obtain unbiased coefficients, other factors that are not accounted for might be driving our results. Two factors are of special relevance: property taxes and other types of stratum-targeted subsidies.[42]

In the case of property taxes, from 1993 until late 2003, right after the ECV2003 survey took place, Bogotá had higher property tax rates for houses in higher strata and, within strata, for those with larger built areas. To assess whether our results are driven by property taxes rather than by SPD subsidies, we include in the 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 1 if the household was a beneficiary of the subsidized regime (SR), the public health insurance that targets the poorest population indirectly, according to socioeconomic stratum.[43] Beneficiaries of the SR receive nearly 1 percent of GDP in health insurance subsidies annually.

Table 11 presents the results after 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 previously found. Nonetheless, even when both the logarithm of the effective property tax rate and the subsidized regime variables are included, each pair of the coefficients on EE and AA are jointly significant at levels higher than 90 percent.

However, our results suggest some evidence of property tax capitalization, with a negative and significant coefficient for the effective property tax rate.[44]

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

43. SR is targeted according to a proxy means test, the SISBEN, which is highly correlated to socioeconomic stratum.

44. We also used an augmented sample that included both the households that reported the amount paid as property tax and those that did not report it, assigning the theoretical rate to the latter. The results did not change significantly.

T A B L E 1 1 . House Price Model, with Additional Controls[a]

	1,000m		800m		700m		600m		500m	
Variable	*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
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
SR	−0.037	−1.47	−0.032	−1.20	−0.049	−1.68	−0.042	−1.62	−0.051	−1.75

Source: Authors' calculations.

m = meters; SR = subsidized regime (see text).

a. The dependent variable is the logarithm of the house appraisal. Results are the equivalent to those reported in table 8 once Ln(τ) (the effective property tax rate) and SR are included. *T* statistics are estimated on the basis of robust standard errors.

In addition, the inclusion of the SR has negligible effects on the relevant coefficients.[45]

Other Potential Biases

Although we think that our results make a good case for the capitalization of public utility subsidies on house prices, our methodology is not free of caveats. First, there are several issues common to hedonic regressions that might be generating bias in our estimates, such as the presence of substantial heterogeneity across households, spatial correlation, and so forth. Second, although the evidence provided supports to a large extent the validity of the RD assumptions listed earlier (namely subsidies change discontinuously at the boundaries and observable and unobservable characteristics of houses change continuously at the boundaries), in the case of the second assumption, whether unobservable as well as observable characteristics change smoothly around the boundaries would still need to be proven. In addition, the third and fourth assumptions (the effect of public utility subsidies on house prices is continuous at the boundaries and the amount of subsidies is independent of its effect on house prices at the boundaries) imply more demanding requirements in our case.

The second assumption would not be satisfied if, for example, differences in preferences across races led individuals from different races to segregate themselves. Since people would value the network that each neighborhood offers differently, that could be an example of an unobservable characteristic that we would not be controlling for that could change discontinuously around the boundaries. In general, since people can estimate in advance the benefits that they could receive from locating on either side of a boundary, one could argue that some sort of sorting around boundaries on unobservable characteristics, such as households' preferences, should be taking place in practice. As long as that sorting becomes a characteristic that affects house prices in a discontinuous way around boundaries, the mechanics of the sorting would imply a violation of the fourth assumption, which in this context would come along with a violation of the second assumption and, in some cases, the third.

45. Intuitively, however, one could expect the inclusion of the SR to have a positive effect on house prices in the future, as the recently implemented "New Sisbén" score is constructed so that households in lower strata have lower scores and so are more likely to be eligible to benefit from SR, thus increasing the probability that a household will be a beneficiary if it moves just across the border between strata (in particular when the household moves from strata 1 or 2 to stratum 3 or higher or vice versa) and affecting house prices much as public utility subsidies do.

The Effect of Eliminating Stratification as a Targeting Mechanism

Given our results, it is natural to ask who the winners and losers would be if the current system of targeting subsidies for public utility services in urban Colombia were abolished. The answer depends on whether households are tenants or homeowners. On the one hand, if a household is a tenant, after the targeting system was abolished it would receive no utility service subsidies, but it would end up paying a lower rent, by an amount similar to the subsidy previously received. Thus the household might be relatively unaffected by the loss of subsidies. On the other hand, if the household is the owner of a rented house, then its wealth would decrease (increase) by an amount equivalent to the present value of the subsidies (taxes) on public utility services that it was receiving (paying) through the higher rent paid by its tenant.

We should bear in mind that our baseline scenario is the current one, in which public expenditure on residential public utility services is doing nothing but distorting relative house prices. Poor households have to pay in advance the present value of the flow of subsidies that their houses provide, while wealthy households pay a lower price for their houses, in an amount equivalent to the present value of the flow of fees that their houses require.

Paradoxically, although the current subsidy scheme only distorts housing prices, individuals would not be indifferent to abolishing it. Table 12 presents the distribution of owner and tenant households by socioeconomic stratum in Bogotá.

As the table shows, the subsidy policy has required about half of the households living in strata 1 to 3 (homeowners) to pay a price for their houses that is higher than the price would have been in the absence of the policy. Eliminating the current subsidy scheme and adopting a flat rate equivalent to the marginal cost to households in any strata would be equivalent to expropriating the value these households paid for their houses under the previous conditions. Furthermore, as the table shows in the middle panel, since 87.7 percent of owner households live in strata 1 to 3, the median voter would be a loser if the current subsidy scheme were abolished, creating a political economy constraint to reform. Put another way, if the current scheme were abolished, homeowners in the poorest strata would require compensation in an amount equivalent to the distortion that the government caused with the scheme itself (which seems to be a budgetary unfeasibility).

Clearly, eliminating the current subsidy scheme would be regressive. But apart from the cost of keeping or modifying the scheme, the question here is whether the government is achieving what it sought to achieve through the sub-

TABLE 12. House Ownership, by Socioeconomic Stratum in Bogotá, 2003

	Number of houses		*Distribution by stratum*		*Ownership by stratum*		
Stratum	*Owner*	*Tenant*	*Owner*	*Tenant*	*Owner*	*Tenant*	*Total*
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	6,762	100.0	100.0	46.9	53.1	100

Source: Authors' calculations.

sidies. 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 it states that "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 distorted under the current scheme because of house prices or rents, then none of those goals are being achieved.

Still, as the current subsidy scheme goes on, the government continues to allow the assignment of nearly 0.7 percent of GDP in gross subsidies to households in strata 1, 2, and 3, 0.3 percent of which comes out of its budget, and of 0.4 percent to households living in strata 5 and 6 and to the commercial, public, and industrial sectors. It thereby ends up doing nothing but distorting relative house prices and the efficient assignment of productive factors such as capital, land, and money, even though it could achieve the above-mentioned purposes through several different mechanisms.

There are several unfavorable side effects of the stratification scheme. On one hand, it offers individuals a perverse incentive to be targeted by the public authorities in charge of assigning subsidies, which, according to the ECV1997 and ECV2003, has led, among other things, to an increase between 1997 and 2003 of 100 percent and 14 percent in the number of households living in strata 1 and 2, respectively, while the number living in strata 4 and 5 decreased 10 percent and 43 percent, respectively. These changes will have direct effects on Colombia's proxy means test targeting system, which recently became highly correlated to socioeconomic stratification.

On the other hand, stratification leads to segregation of the poorest and the richest communities. Reversing that segregation would seem infeasible if we accept as reasonable a claim by Grodzins, as quoted by Schelling: "Once an urban area begins to swing from mainly white to mainly black, the change is rarely reversed."[46]

Other schemes, based on instruments like the SISBEN, which allows ordering of households from the poorest to the richest according to their permanent income, could be considered for targeting subsidies for public utility services. Such a mechanism is being used in Colombia to target demand subsidies for health services by providing health insurance for the poor. As mentioned previously, the government spends about 1.0 percent of GDP a year on the program; resources currently used to subsidize public utility services would be enough to increase that budget by 70 percent.[47] In addition, according to Medina and Morales (2007), deadweight losses associated with electricity and water subsidies amount to nearly 5 percent and 10 percent, respectively. This implies that if we eliminated subsidies for public utility services and transferred to households the required compensated variation—that is, the income households would require to keep their utility when they are charged the cost rather than the subsidized price of the service—households would end up as well-off as they were with subsidies, housing prices would not be distorted, and Colombia would save up to US$35 million a year previously spent on efficiency losses, much more than what would be required to keep the SISBEN mechanism working, estimated at about US$7 million every five years.

If, on the one hand, the government wanted to eliminate stratification as its targeting mechanism, an option for dealing with the potential political economy restrictions would be to do it over a very long period of time, say twenty years, while simultaneously introducing another mechanism, such as the SISBEN.

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

46. The statement is by Grodzins (1957), as quoted by Schelling (1972). 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 between segregated groups on several outcomes), mobility, and test scores (higher segregation implying a higher test score gap between groups)

47. Benefits from better access to health services are less likely than are benefits from public utility service subsidies to end up being auctioned in the market, and they are more likely to achieve the goals sought by the government through its public utility services policy.

Conclusions

Cross-subsidy schemes have been widely used in Latin American countries to deliver residential public utility services (electricity, piped water and sewer services, and piped gas) to the low-income population at below-cost rates while the higher-income population contributes by paying rates above the cost of service. While there is a consensus in most countries on the desirability of subsidizing the consumption of public utility services, policies have focused on minimizing the inefficiencies implied in subsidies and making targeting methods more effective.

Colombia has a cross-subsidy system that charges subsidized rates to households that live in houses located in strata associated with low wealth levels and taxed rates to households that live in strata associated with high levels of wealth.

The consumption of residential public utility services is nontransferable. Nonetheless, this paper assesses the hypothesis that the flow of subsidies that might be received by occupants of a specific house could be discounted by housing market agents, with the result that most of the subsidies end up being transferred to the price of the house that generates them rather than staying in the pockets of the house's occupants.

To estimate the effect that subsidies for residential public utility services can have on house values, we compared the prices for houses on both sides of the boundary between different socioeconomic strata—that is, houses subject to different public utility service rates—and found that the increment in house value is similar in magnitude to the present value of the flow of subsidies discounted at reasonable market rates. Rent amounts are similarly affected by the subsidies.

Although the results include information only for Bogotá, we think that they would be consistent with the current situation in Colombia's major cities. The discussion above leads us to conclude that the goals of providing subsidies to the poor population through public spending on residential public utility services in Colombia are being achieved, if at all, in a very limited way. The final effect of most of the fiscal effort in this area has been to distort house prices in different socioeconomic strata. While the system assigns 0.7 percent of GDP each year in supposed gross subsidies for residential public utility services, the only thing it ends up doing is introducing an additional characteristic (subsidies, which would not exist without government intervention), to which the housing market then assigns a price, consequently distorting the relative prices of housing.

The evidence contained in this paper calls for a review of the targeting policies for subsidies for residential public utility services in Colombia and other countries in the region that have similar schemes. It is important to continue gathering evidence that could allow for generating consensus on the benefits and limitations of this type of scheme, because an eventual reform of them would at first face significant political economy constraints, which have been and will continue to be a bottleneck in the achievement of more efficient and better-targeted subsidies.

APPENDIX A-1. Comparison of Means of Characteristics between Better and Worse Sides of the Boundaries[a]

	Distance (meters)				
Variable	*750*	*500*	*250*	*150*	*125*
House valuation	−0.68	−0.85	1.30	1.09	−1.48
House valuation per square meter[b]	−5.90	−6.75	−6.15	−1.78	−0.55
Logarithm of house valuation	−4.21	−3.39	−1.90	−1.00	−2.42
Logarithm of house valuation per square meter[b]	−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 courtyard	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
House with damage due to 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
Feeling of safety in 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
Kitchen is separate room in the house	−2.40	−1.98	−3.15	−1.97	−1.41
House[c]	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: floor tile, vinyl, tablet, or wood	−2.87	−2.35	−0.28	0.58	0.01
Floor material: coarse wood, table, or plank	0.89	1.63	2.28	1.29	1.88
Floor material: cement, gravilla, earth, or 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 (square meters)	3.46	4.12	4.75	2.52	0.15
Built area (square meters)	0.93	2.26	4.77	3.84	1.56
Number of observations (full sample)	3,956	3,388	2,034	1,011	652
Number statistically 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

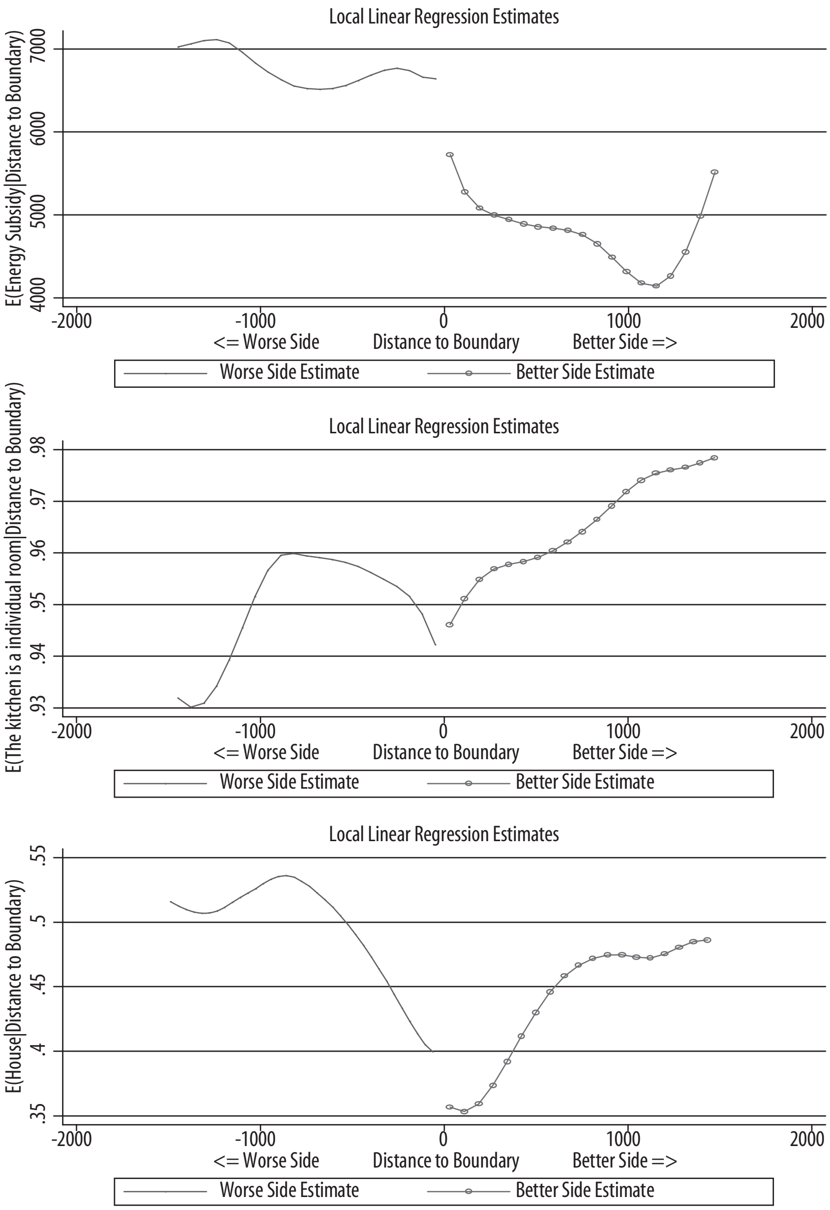
Sources: Encuesta de Calidad de Vida 2003 (ECV2003, or Living Standards Measurement Survey of 2003); District Real Estate Appraisal of the Administrative Department for the District Cadastre of Bogotá (to be referred to as DACD), data collected in 2000 (see text for details).

a. Local linear regressions yield *t* statistics that 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. There are eighteen frontiers that have on one side stratum 2 and on the other stratum 3, ten with strata 1 and 2, sixteen with strata 3 and 4, six with strata 4 and 5, and four with strata 5 and 6.

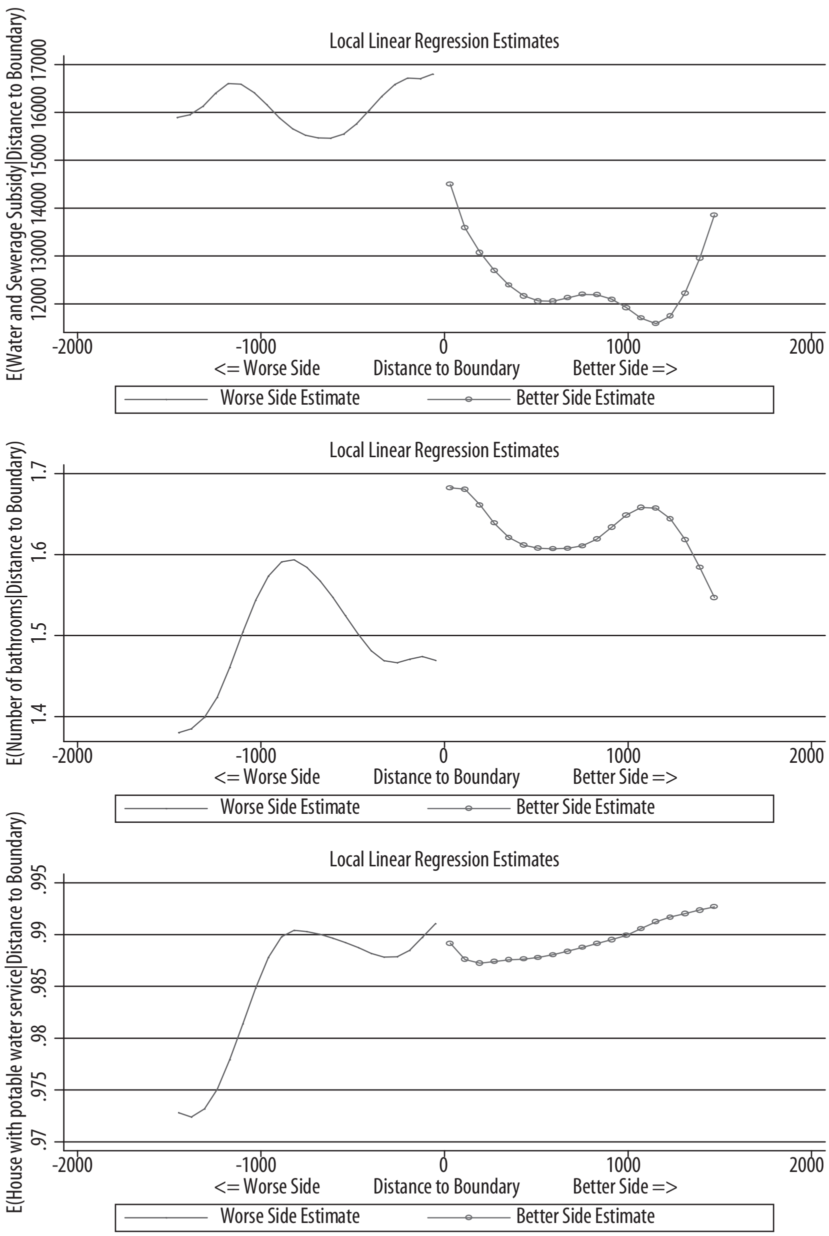
b. The square meters used are the sum of those of the land plus those of the building.

c. Dummy = 1 if living in the house (as opposed to an apartment, and so on.).

APPENDIX A-2. Local Linear Regression Estimates for Better and Worse Sides of the Boundaries between All Strata[a]



APPENDIX A-2. Local Linear Regression Estimates for Better and Worse Sides of the Boundaries between All Strata[a] *(continued)*



Sources: See appendix A-1.

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

APPENDIX A-3. Local Regression Estimates and *t* Statistics Obtained by Comparing Means of Characteristics between the Better and Worse Sides of Boundaries between All Strata[a]

	Better side		Worse side		
Variable	*E(Distance ≈ 0)*	*Std. err.*	*E(Distance ≈ 0)*	*Std. err.*	t
Logarithm of house valuation	12.105	0.062	12.117	0.047	−0.2
Logarithm of house valuation per square meter[b]	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	0.08 1	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	0.3 10	0.052	0.182	0.046	1.8
Parks in neighborhood	0.135	0.030	0.042	0.030	**2.2**
House with damage due to 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
Feeling of safety in 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
Kitchen is separate room in the house	0.973	0.018	0.952	0.028	0.6
House[c]	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: floor tile, vinyl, tablet, or wood	0.682	0.049	0.783	0.050	−1.4
Floor material: coarse wood, table, or plank	0.025	0.013	0.042	0.017	−0.8
Floor material: cement, gravilla, earth, or 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 (square meters)	150.714	8.624	153.633	12.520	−0.2
Built area (square meters)	105.251	8.077	90.451	7.291	1.4
Number statistically different from zero					4
Total number of active controls					32
Percentage of active controls different from zero					12.5

Source: See appendix A-1.

Std. err. = standard error.

a. Local linear regressions yield *t* statistics that test 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 zero. 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 600m were used in the LLR regression. Bootstrap standard errors are obtained based on 100 replications with 100 percent sampling.

b. The square meters used are the sum of those of the land plus those of the building.

c. Dummy = 1 if living in the house (as opposed to an apartment, and so on.).

APPENDIX A-4. Summary Statistics

	Complete information		*Incomplete information*			
Variable	*Mean*	*Std. dev.*	*N*	*Mean*	*Std. dev.*	*Difference*[a]
House valuation	51,200,000	41,600,000	3,587	55,300,000	72,200,000	+
House valuation per square meter[b]	225,470	158,686	3,585	185,195	153,181	+
Logarithm of house valuation	17.49	0.7	3,587	17.46	0.8	
Logarithm of house valuation per square meter[b]	12.13	0.6	3,585	11.91	0.6	+
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 courtyard	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	+
House with damage due to 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	
Feeling of safety 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	+
Kitchen is separate room in the house	0.980	0.140	7,479	0.947	0.225	+
House[c]	0.456	0.498	7,479	0.322	0.467	+
Wall material: brick, block, stone, or polished wood	0.986	0.116	7,479	0.973	0.163	+

(continued)

APPENDIX A-4. Summary Statistics *(continued)*

	Complete information		*Incomplete information*			
Variable	*Mean*	*Std. dev.*	*N*	*Mean*	*Std. dev.*	*Difference*[a]
Floor material: marmol, parquet, or 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: floor tile, vinyl, tablet, or wood	0.618	0.486	7,479	0.578	0.494	+
Floor material: coarse wood, table, or plank	0.044	0.205	7,479	0.062	0.241	+
Floor material: cement, gravilla, earth, or sand	0.110	0.3 13	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 (square 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	+
Built area (square 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					

Source: See appendix A-1.

a. Variables with a statistically significant difference are designated by +.

b. The square meters used are the sum of those of the land plus those of the building.

c. Dummy = 1 if living in house (as opposed to an apartment, and so on.)

APPENDIX A-5. House Price Model Results Using Basic OLS Regression[a]

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 courtyard	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
House with damage due to 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
Feeling of safety 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
Kitchen is separate room in the house	0.1054	2.7
House[b]	−0.1301	−13.1
Wall material: brick, block, stone, or polished wood	0.0254	0.6
Floor material: marmol, parquet, or lacquered wood	0.0049	0.2
Floor material is carpet	0.0548	2.4
Floor material: floor tile, vinyl, tablet, or wood	0.0136	0.7
Floor material: cement, gravilla, earth, or 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 (square 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

(continued)

APPENDIX A-5. House Price Model Results Using Basic OLS Regression[a] *(continued)*

Variable	*Coefficient*	t
Interaction variable Land*stratum6	–0.0008	–1.6
Built area (square 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	

Sources: See appendix A-1.

OLS = ordinary least squares.

a. These coefficients resulting from estimating equation 1 are 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 Bogotá's neighborhood fixed effects (19) are.

b. Dummy = 1 if living in the house (as opposed to an apartment, and so on.).

Comments

Raquel Bernal: In this paper, the authors seek to evaluate the effects of the cross subsidy–stratification system for public utility services on housing prices in Bogotá, Colombia. In addition, they use their estimates to assess the extent to which the distortions in housing prices associated with the subsidy–stratification system affect final subsidy beneficiaries. Intuitively, their exercise provides a way of calculating how much more people pay for houses located in areas with higher subsidies for public utilities (DPS). Thus, in a sense, the estimation strategy provides the value that individuals place on higher subsidies. Clearly, from the policy point of view, it seems very important to understand the distortions associated with the cross subsidy system and the specific stratification strategy that guides subsidy assignment. From both these perspectives, this paper is an important contribution.

The basic estimation strategy is to estimate a relatively standard hedonic price model in which public utility subsidies received or paid by a given dwelling have an effect on the price of the house, controlling for a variety of observed characteristics of the house and the neighborhood. The key issue dealt with in the paper is the endogeneity of the subsidy in such an equation. In other words, estimating the causal effect of DPS subsidies on housing prices is difficult because houses that receive high subsidies are located in lower socioeconomic strata (that is, poorer neighborhoods) and thus are associated with lower prices. Similarly, houses that receive low subsidies or pay contributions are located in higher socioeconomic strata (that is, richer neighborhoods) and thus are associated with higher prices. Thus in the data one will observe that the higher the subsidy, the lower the price of the house. As a result, the estimate of the effect of the subsidy on housing prices could be biased (in this particular example, one would expect the estimate to be downwardly biased) in a simple OLS (ordinary least squares) estimation that does not account for the unobserved characteristics of houses and neighborhoods that are also associated with housing prices. The critical issue is, then, that all relevant characteristics pertaining to house, neighborhood, and stratum are not observed or measured. Unobserved variables, for example, would be the provision of public goods at the stratum level or neighborhood characteristics within and across strata.

To deal with this issue, the authors implement a type of regression discontinuity design (RDD) by taking advantage of the stratification system by which households are assigned to one of six socioeconomic strata that are then used to target differential subsidies for public utility services. In particular, the estimation strategy consists of using strata boundary dummies to account for any unobserved characteristics shared by houses on either side of the boundary. Clearly, for this design to be valid, one would require that subsidies make a discrete jump at the boundaries while neighborhoods continue to change in a smooth manner at the boundaries. Intuitively, the authors claim that while there is significant heterogeneity across strata and, as expected, homogeneity within stratum the location of the exact boundaries can be arbitrary to a great extent because a very large number of dwellings were assigned to very few groups (six in total). Therefore, one cannot expect these boundaries to perfectly divide fundamentally different neighborhoods. Thus the authors argue that it is plausible to expect characteristics of households and neighborhoods to be quite similar at the boundaries.

However, one must be aware of the fact that the key assumption of the regression discontinuity design would be plausible in cases in which boundaries are determined according to characteristics uncorrelated with the independent variables in the hedonic price equation (and, in particular, the subsidy, which is the variable of interest) and the unobserved error term. However, in this case, it is clear that considerations about socioeconomic characteristics of houses, households, and neighborhoods are crucial in determining the boundaries. The results reported in the paper indicate that, in fact, even for houses located very close to the boundary, at least 50 percent of the observed characteristics of dwellings are statistically significantly different on both sides of the boundary. These results might suggest that the stratification strategy does in fact successfully take into account differences in households to set the boundaries.

In table 8, the authors report a summary of their findings. In particular, the elasticity of housing prices to energy subsidies goes from 0.0270 in the OLS estimation to 0.0363 in the estimation with 500-meter boundaries.[1] This

1. The estimated elasticity is 0.0297 if, in addition, one uses instrumental variables to correct for measurement error present in the stratum reported by individuals.

implies that OLS produced an *underestimated* value of the effect of subsidies on housing prices, although the difference between the two estimators is not statistically significant. On the other hand, the effect of water (and sewerage) subsidies on housing prices goes from 0.0331 in OLS to 0.0258 with 500-meter boundaries (and 0.0295 with boundaries and instrumental variables). In other words, OLS *overestimated* the effect of water subsidies on housing prices. Yet again, the difference between the two estimators is not statistically significant.

Two things are worth emphasizing about these results: the OLS bias for energy subsidies and that for water subsidies go in opposite directions and the difference between the OLS estimate and the estimate with stratum boundaries is not statistically significant (for energy and water subsidies). On the one hand, the latter finding could suggest either that the proposed strategy does not handle the endogeneity issue adequately or that there were no endogeneity issues to begin with. Unfortunately, there is little discussion in the paper about the expected direction of the bias and the RDD results in this sense. On the other hand, the former finding might suggest that the explanatory variable of interest—the subsidy for public utilities—is not appropriately measured and might be capturing other dimensions of heterogeneity (which, in addition, differ by type of utility service) that are not fully captured by the strata boundaries.

In particular, note that the explanatory variable is calculated as the total monthly subsidy (contribution) received (paid) by the household. That means that the subsidy variable captures both: variations in prices associated with the cross subsidy structure and variations in prices associated with differences in demand. In other words, a high subsidy amount (the key explanatory variable) might be due to the subsidy schedule, that is, the subsidy amount per unit or the total demand for that particular public utility. In fact, in figure 1 and tables 3 and 4, the authors show that there is significant variation in monthly subsidy amounts within stratum, which suggests significant differences in demand even within stratum.[2]

The identification assumption in RDD requires that the only difference between houses at each side of the boundary be that houses located to one side are subject to a given intervention and the ones on the other side are not (or are subject to a different intervention). In this case, however, the intervention *S* (subsidy) is a composite of the intervention per se, that is, the differences in DPS price associated with the cross subsidy structure and differences

2. Recall that all housing units within one stratum face the same subsidy (or contribution) schedule by the public utility service.

in demand that exist even conditional on observed characteristics of houses and neighborhoods. So, for example, if households that demand more utility services are better off, presumably living in better houses (in dimensions that might be unobserved for the researcher), then the effect of the subsidy on housing prices might be upwardly biased and the boundary dummies can be controlling for that type of heterogeneity.[3]

An interesting component of the paper consists of using the estimated elasticities to assess the effects of subsidies on final beneficiaries. In particular, the authors compare the net present value of average annual subsidies (by utility service) with the change in housing prices due to a 100 percent change in the subsidy, with the objective of evaluating how much of the subsidy is really appropriated by the beneficiary household. These results are presented in table 9. Using a 10 percent annual real interest rate, the authors find that the DPS subsidies are transferred almost entirely to housing prices. The rationale behind this policy experiment is that a 100 percent change in the subsidy is equivalent to moving from "no subsidy" to "subsidy," that is, it is equivalent to changing stratum.

Although this is an interesting thought experiment, it is unrealistic in the sense that not every move between any pair of strata is associated with a 100 percent change in the subsidy (or contribution) that the household receives (or pays). In other words, the percentage change in the subsidy amount received (or contribution paid) associated with a move crucially depends on the origin and the destination. One way to do this more accurately is to calculate the percentage difference in *average* subsidies (contributions) received (paid) by households in different strata and to use the estimated elasticities to assess the effect of each move on housing prices.[4]

These results are presented in table 13 below. I use the data presented in table 5 to calculate the percentage change in average subsidy amounts between two adjacent strata.[5] I then use this number and the estimated elasticities of subsidies on housing prices to assess the average effect of moving from one stratum to another on housing prices.

3. As mentioned before, the OLS effect of subsidies for water and sewage on housing prices seems to be in fact upwardly biased, contrary to the initial intuition that pointed to downward biased estimates.

4. In addition, we evaluate the effect on average housing prices at destination, instead of on city average housing prices.

5. Note that, in fact, the percentage difference between subsidies received in two adjacent strata vary significantly depending on the pair of strata being compared. This difference ranges from 21 to almost 150 percent.

TABLE 13. Average Effects of Moving from One Stratum to the Adjacent Stratum

	A	B	C	D	E	F	G
	Elasticity	*Δ avg S*	*Percentage Δ avg S*	*Implied percentage Δ in house price (A*C)*	*Δ housing price (at average within stratum)*	*NPV Δ annual subsidy (B*12/0.1)*	*NPV/ Δ price (F/E)*
Electricity							
Δ from stratum 2 to 1	0.0297	2,614	21.7	0.64	132,143	313,680	2.37
Δ from stratum 3 to 2	0.0297	7,185	147.9	4.39	1,229,686	862,200	0.70
Water							
Δ from stratum 2 to 1	0.0295	6,331	23.7	0.70	143,396	759,720	5.30
Δ from stratum 3 to 2	0.0295	13,617	104.1	3.07	859,714	1,634,040	1.90

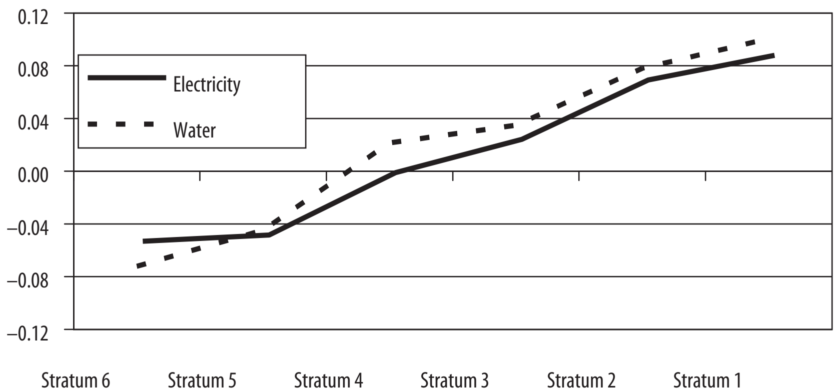
Source: Author's calculations based on data reported in tables 5 and 8.
NPV = net present value; *S* = subsidy; Δ = change; avg = average.
a. Average subsidies, housing prices, and annual subsidies (B, E, and F) are in Colombian pesos.

Note that only in the case of a change from the average electricity subsidy in stratum 3 to the average electricity subsidy in stratum 2 is the net present value of average annual subsidies lower than the implied effect on housing prices. That means that in this case the change in DPS subsidy is entirely transferred to housing prices. However, note that in all other cases, the number in column G is bigger than 1, which implies that the net present value of annual subsidies due to a move from one stratum to another (for example, from stratum 2 to stratum 1) is significantly larger than the implied effect of this change on housing prices. In some cases, this difference is actually large. For example, the net present value of the change in water subsidies due to a move from stratum 2 to stratum 1 is five times bigger than the increase in housing prices due to that particular move.

In sum, while there is evidence that in one case the subsidy might be entirely transferred to housing owners, in all other cases beneficiary households actually benefit from the subsidy even after one takes into account the change in housing prices associated with the change in the subsidy amount.

Finally, although the authors estimate a flexible quadratic function of the subsidy, these nonlinearities are not fully exploited in the analysis, although most of these quadratic terms are actually statistically significant. In figure 3 below, I show average elasticities of housing prices to subsidy amounts by stratum. The results are interesting in the sense that they suggest that the estimates imply significant differences across strata. In particular, the elasticities in stratum 1 (which corresponds to the poorest neighborhoods) are close to 8 percent while elasticities in the top strata are, of course, negative but half

FIGURE 3. Average Elasticity of Housing Prices with Respect to DPS Subsidies, by Stratum



Source: Author's calculations based on data reported in tables 5 and 8.

the size of those found in the poorest neighborhoods. The reduction in the elasticity is about 65 percent when one moves from stratum 1 to stratum 3 (both of which receive subsidies).

In sum, the results presented in the paper are interesting, as they suggest that people are willing to pay more for houses located in areas with higher subsidies for public utilities (DPS). Although the different estimation strategies do not provide statistically significantly different estimates of the relevant elasticities (which as we have discussed might be disappointing), the various estimates indicate that housing prices are quite responsive to DPS subsidies and that in some cases these elasticities are actually quite high (for example, the elasticity of housing prices in stratum 1 with respect to DPS subsidies is around 8 percent). However, if one makes careful comparisons of what would happen were an individual to move from one stratum to another, in most cases, the change in the net present value of subsidies would still be higher than the implied change in housing prices. That means that the benefit for the beneficiary of the DPS subsidy is higher than the cost implied by it in terms of changing housing prices.

Maximo Torero: This paper assesses the hypothesis that the flow of subsidies for utility services is discounted by real estate agents' transferring most of them to the prices of targeted houses. In this sense, these subsidies would not stay in the pockets of households that reside in them.

The authors find that the estimated increment in house value due to subsidies is similar to the present value of the flow of subsidies discounted at reasonable market rates. Analogous effects are found in the value of rents. Thus targeting subsidies for public services to poor strata may generate a distortion of house prices in different socioeconomic strata.

The authors are taking advantage of the unique characteristics of the real estate market, which are that housing cannot be easily moved, that it is durable and expensive, and that moving to a new place is costly both monetarily and emotionally. In this sense, these characteristics allow the authors to effectively track the housing subsidies in Colombia and thus to tackle some important issues. I would like to organize my comments in two areas. First, I would like to raise some concerns regarding the difficulty of modeling the real estate market under heterogeneous conditions. In particular, I would like to address two issues: first, the vast array of characteristics that have to be accounted for so as to avoid bias in the estimations and the challenges one faces in finding equilibrium prices. Second, I would like to discuss possible problems of endogeneity, the potential presence of spatial autocorrelation, and differences in elasticities across sectors in the methodology.

Modeling the Real Estate Market under Heterogeneity

There is an inherent heterogeneity in the real estate market as each house or apartment offers a different bundle of housing "services," such as dwelling characteristics (size, layout, kitchen appliances, heating and air conditioning systems, structural integrity, and so on), and community features (accessibility to jobs, shopping centers, entertainment venues, parks, good schools, police control, air quality, noise levels; among others). Other sources of heterogeneity come from housing cross subsidies, as raised by the authors, and direct subsidies, which are not considered in the analysis. The problem is that, if all these characteristics are not accounted for, bias could arise from significant measurement error. This is crucial when one estimates the equilibrium price.

One alternative could be to summarize the characteristics of the household using Polychoric Principal Component Analysis.[1] Polychoric indexes have a

1. Kolenikov and Angeles (2004).

number of advantages. The most important one comes from its use of ordinal data. Many assets can be described as ordinal. Specifically in this paper the authors are interested in the quality of house construction, which might be recorded on a 1 to 4 scale. Filmer and Pritchett advocate splitting this ordinal variable into four binary ones.[2] Nevertheless, this introduces a large amount of distortion into the correlation matrix, as these binary variables have, by construction, a perfect negative correlation with each other. Furthermore, the notion that some values are better than others is lost, as the dummy approach gives equal treatment to all the variables. Polychoric indexes solve these problems by assigning each category a discrete value and ensuring that the coefficients of an ordinal variable follow the order of its values. Finally, another of their advantages is that they allows one to compute coefficients of both owning and not owning an asset. This is desirable because sometimes not owning something conveys more information than owning it. For example, if most households have indoor plumbing except for the poorest ones, having this service will not provide useful information to distinguish wealth levels. Nevertheless, not having it will certainly help identify those worse off in the distribution.

Furthermore, the literature on the hedonic approach has focused on the complications that arise from heterogeneity of households. In the heterogeneous case, the equilibrium price function is an upper envelope of the bid price function. In this sense, it is a bid price function, and not the equilibrium price function, that represents a household's willingness to pay for properties. Since the paper uses the latter instead of the former, it is implicitly assuming identical preferences of households and may overestimate the benefits of amenities.

In addition, apparently there is an important variability in the public services targeting mechanism. The targeting mechanisms of public services change over time, and specifically this seems to happen in the Colombian case. But how do agents capture this? Would it not be better to calculate the expected value of future flows of subsidies without correcting for uncertainty?

Finally, from the document it is not clear what subsidies are being taken into account. Initially, there is some detail on electricity and later on water; but this needs to be clarified. This point is crucial because different utilities offer different subsidy schemes. For example, subsidy schemes may be based on consumption, they may have nonlinear schedules, they may be metered or

2. Filmer and Pritchett (2001).

not, they may impose minimum consumption, and so forth. As all these factors may vary across utilities, as well as in time, it would be useful to know how the authors have dealt with these issues. Also of interest are details on how other subsidies at the municipality level (such as property taxes or schools of different qualities, to name a few) are considered in the analysis.

Methodological Issues

As mentioned before, household heterogeneity imposes some modeling and estimation complications. In this sense, controlling for heterogeneity requires a vast set of characteristics. But even assuming there is no problem of omitted variables, there are three issues that the authors need to be concerned about in their future research.

A first issue comes from the endogeneity of the potential subsidy. Families might probably select themselves to areas with high subsidies, so there is a need to instrumentalize this subsidy. Even when strata from the Living Standards Measurement survey (*Encuesta de Calidad de Vida* [ECV]) of 2003 are instrumentalized using the Administrative Department of District Real Estate Appraisal (DACD) of 2000, the endogeneity problem is likely to persist. On one hand, there is a three-year lag in the instrument, and on the other, this instrument is still based on household self-reports. Under these circumstances, it is still not clear if the instrument should be necessarily orthogonal to the error term.

Secondly, with regard to the regression discontinuity method, there are three problems I would like to mention. One is that the authors assume that houses in near neighborhoods have similar characteristics. This might be problematic since characteristics might not be the same among households in neighbor boundaries. In any case, this assumption needs to be validated, and some robustness tests are required. Moreover, if the assumption of neighborhood homogeneity is accepted, there is a likelihood of spatial correlation problems: housing prices may be determined by using comparable dwellings in similar neighborhoods as benchmarks.

A third problem arises from the fact that the authors use a vector of dummies instead of a matrix of dummies (that is, dummies should be specific to the two strata, so sets of dummies should be created for different pairs of neighbor districts and not one common dummy). This is important because if dummies are not specific for particular strata then households are being compared on joint neighbors, while they are treated the same as pairs from different districts. Why not restrict the data to the neighbor pairs? For future research it will be interesting to see whether the authors use "distance between neighborhoods" instead of dummies, which could also help control for spatial autocorrelation and help implement regression discontinuity as discussed by Hahn, Todd, and Van der Klaauw.[3]

Finally, elasticities of demand price used to calculate the subsidies are imputed from López, Castaño, and Vélez and Vélez, Botero, and Yánez, and the same elasticity is used across socioeconomic sectors.[4] Nevertheless, it has been shown that the elasticity changes between socioeconomic strata, as discussed by Wolak and by Pollak and Wales.[5]

3. Hahn, Todd, and Van der Klaauw (2001).
4. Lopez, Castaño, and Vélez (1992); Vélez, Botero, and Yánez (1991).
5. Wolak (1995); Pollak and Wales (1980, 1981).

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