Housing Demand in the Developing Metropolis

Estimates from Bogota and Cali, Colombia

Gregory K. Ingram

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ABSTRACT

This paper presents estimates of housing demand equation parameters separately for owners and renters in Bogota and Cali, Colombia in 1978, and for Bogota renters only in 1972. The demand estimation procedure uses a work place based stratification to introduce price variation in the equations.

The demand equations estimated using this procedure give very significant results for the income elasticity of the demand for housing, with estimates of the income elasticity generally lying in the upper end of the range 0.2 to 0.8, although the price term in the demand appears to be less than one. Other household characteristics involved in the demand equations have low demand elasticities, typically less than 0.5 in absolute magnitude. The age of the head has a positive elasticity over most of its range while family size usually has a positive elasticity for renters and a negative elasticity for owners. The demand equations suggest that female headed households consume more housing than male headed households, but this result is rarely statistically significant. Distance from home to work is entered into the demand equations as an adjustment to income, but it is undoubtedly also representing price variation within the workplace strata that are used as the main representation of price variation. The distance elasticity is small, less than -0.2, and is almost always negative.

Comparisons of elasticity estimates with those obtained from U.S. data sets indicate that the range of the Colombian estimates generally overlaps the range of the U.S. estimates. Simple experiments involving the aggregation of the houshold survey data used to obtain micro data estimates suggest that income elasticity estimates based on correctly aggregated data can be good proxies for estimates based on fully specified models using household observations. At the same time, estimates based on micro data that are incorrectly aggregated can produce estimates of the income elasticity of demand that are badly biased.

EXTRACTO

En este documento se presentan estimaciones sobre parámetros de la ecuación de la demanda de vivienda en forma separada para propietarios y para inquilinos en Bogotá y Cali, Colombia, en 1978 y para inquilinos únicamente en Bogotá, en 1972. En el procedimiento de estimación de la demanda se usa una estratificación basada en el lugar de trabajo a fin de tomar en cuenta el efecto de las diferencias de precio en las ecuaciones.

Las ecuaciones estimadas con este método presentan resultados muy significativos con respecto a la elasticidad de la demanda de vivienda en función del ingreso, la que en general se sitúa en el extremo superior de la escala de 0,2 a 0,8, aunque el elemento del precio parece ser inferior a la unidad. Las demás características de las unidades familiares que intervienen en las ecuaciones de la demanda tienen elasticidades bajas de demanda, generalmente inferiores a 0,5 en términos absolutos. La edad del jefe de la familia tiene una elasticidad positiva en la mayor parte de su gama, en tanto que el tamaño de la familia suele tener una elasticidad positiva en lo que respecta a los inquilinos y negativa en lo que respecta a los propietarios. Las ecuaciones de la demanda indican que los hogares cuyo jefe es una mujer consumen más vivienda que aquellos encabezados por un hombre, pero este resultado rara vez es estadísticamente importante. La distancia de la vivienda al lugar de trabajo se introduce en la ecuación como un ajuste al nivel del ingreso, pero sin duda representa también una variación del precio dentro de los estratos del lugar de trabajo que se emplean como la representación principal de la variación de precios. La elasticidad de la distancia es pequeña, inferior a -0,2, y casi siempre es negativa.

La comparación de estas estimaciones de la elasticidad con las obtenidas de series de datos estadounidenses indica que la gama de estimaciones colombianas es en general semejante a la gama de las estadounidenses. Experimentos sencillos que involucran la agregación de los datos de encuestas de hogares utilizadas a fin de obtener estimaciones de datos al nivel de la unidad familiar indican que las estimaciones de la elasticidad-ingreso basadas en datos agregados correctamente pueden ser buenos sustitutivos de los cálculos basados en modelos totalmente especificados usando observaciones directas de los hogares. Al mismo tiempo, las estimaciones basadas en datos al nivel de la unidad familiar agregados incorrectamente pueden producir estimaciones de la elasticidad-ingreso de la demanda sumamente sesgadas.

Ce document présente une estimation des paramètres des équations de la demande de logement pour les propriétaires et les locataires de Bogota et de Cali (Colombie) en 1978 et pour les locataires de Bogota seulement en 1972. Pour établir les estimations de la demande, on a utilisé une stratification fondée sur le lieu de travail pour introduire les variations de prix dans les équations.

Les équations de la demande établies grâce à cette méthode donnent des résultats très significatifs sur l'élasticité-revenu de la demande de logement, les estimations de l'élasticité-revenu se situant généralement dans l'extrémité supérieure de la fourchette 0,2 à 0,8, bien que l'élément prix de la demande semble être inférieur à un. Pour les autres caractéristiques des ménages dont on a tenu compte dans les équations de la demande, l'élasticité de la demande est faible, généralement inférieure à 0,5 en valeur absolue. L'élasticité en fonction de l'âge du chef de famille est positive pour la plus grande partie des tranches d'âge considérées, alors que l'élasticité en fonction de la taille de la famille est généralement positive pour les locataires et négative pour les propriétaires. Il ressort des équations de la demande que les ménages dirigés par des femmes ont une plus forte consommation de logements que les ménages dirigés par des hommes, mais ce résultat est rarement significatif sur le plan statistique. La distance du domicile au lieu de travail est prise en compte grâce à un ajustement du revenu, mais il est évident qu'elle représente également des variations de prix dans les strates établies en fonction du lieu de travail, qui sont le principal moyen de représentation des variations de prix. L'élasticité en fonction de la distance est faible, moins de -0,2, et elle est presque toujours négative.

Si l'on compare ces estimations de l'élasticité à celles que l'on obtient à partir de séries de données pour les Etats-Unis, on constate que, dans l'ensemble, ces estimations se recouvrent. Il ressort d'expériences simples comportant l'agrégation des données provenant d'enquêtes sur les ménages utilisées pour obtenir des micro-données que les estimations de l'élasticité-revenu établies d'après des données correctement agrégées peuvent être un bon substitut aux estimations étblies d'après des modèles complets et d'observations sur les ménages. Mais des estimations de l'élasticité-revenu de la demande tirées de micro-données mal agrégées peuvent être fortement biaisées.

PREFACE

This paper forms part of a large program of research grouped under the rubric of the "City Study" of Bogota, Colombia, being conducted at the World Bank in collaboration with Corporacion Centro Regional de Poblacion. The goal of the City Study is to increase our understanding of the workings of five major urban sectors -- housing, transport, employment location, labor markets, and the public sector -- in order that the impact of policies and projects can be assessed more accurately.

The author has benefitted from comments and discussions with Vinod Thomas, Michael Hartley, Steve Mayo, Janet Pack, Peter Schmidt, Joseph de Salvo and participants in seminars at Princeton, Michigan State, MIT, The World Bank, and Corporacion Centro Regional de Poblacion. He thanks Songyong Kang for research assistance, Maria Elena Edwards for manuscript preparation, and the staff of Departamento Administrativo Nacional de Estadistico, Colombia, for aid with the data.

Other City Study Papers dealing with housing and housing markets include:

1. Rafael Stevenson, "Housing Programs and Policies in Bogota: An Historical/Descriptive Analysis", Water Supply and Urban Development Department Discussion Paper, No. 51, The World Bank, Washington D.C., 1984.

2. Alan Carrol, "Pirate Subdivisions and the Market for Residential Lots in Bogota", World Bank Staff Working Paper No. 435, Washington D.C., October 1980.

3. Andrew M. Hamer, "Bogota's Unregulated Subdivision: The Myths and Realities of Incremental Housing Construction", Urban and Regional Report No. 81-19, The World Bank, Washington D.C. 1981. Also appeared in Revista Camera de Comercio de Bogota, Nos. 45-46, pp. 9-81, December 1981. (City Study Project Paper No. 24).

4. _____, "Household and Housing: Residential Mobility, Tenure Choice, and Space Consumption in the Developing Metropolis," Urban and Regional Report No. 81-20, The World Bank, Washington D.C. 1981. (City Study Project Paper No. 26).

5. Jose Fernando Pineda, "Residential Location Decisions of Multiple Worker Households in Bogota, Colombia", Unpublished Ph.D. Dissertation, University of California, Berkeley, California, 1981

Table of Contents

I. INTRODUCTION

This paper reports three sets of results related to the estimation of housing demand equations. First, it presents estimates of housing demand parameters based on household interview data from Bogota and Cali, Colombia. A comparison of parameter values to those obtained from North American data sets shows that the Colombia demand elasticities are generally comparable in magnitude to those from the United States. Second, the approach employed to represent housing price variation in the demand equations uses a theoretically attractive and computationally straight forward procedure that is based on residential location theory. Finally, a simple exercise illustrates the magnitude of bias of the income elasticity of demand that can result from incorrect data aggregation techniques. Moreover, correctly aggregated data produce income elasticity estimates that are similar to those obtained from disaggregate or micro data.

II. THE PRICE TERM IN HOUSING DEMAND EQUATIONS

Estimating demand equations for housing from cross sectional data presents many challenges, but measuring the variation in the unit price of housing is probably one of the greatest difficulties. Data sets typically report the total expenditure on housing rather than a unit price and quantity of housing. Hence the unit price must be inferred by relating variations in expenditure to variations in quantity. Moreover, housing is inherently multidimensional, including attributes of size, dwelling quality, location, public services, and neighborhood

amenities that are obtained in a single tied purchase. Since there is no widespread agreement as to how we should measure the quantity of housing, one analyst's price variation may be another analyst's quantity variation. Finally, even if we can agree that housing prices may vary, it is not obvious that all price variation is relevant for inclusion in a housing demand equation. For example, if a metropolitan area's housing prices vary with the quantity of housing but households can locate anywhere, we cannot simply put the price actually paid by the household into the demand equation because the household faces the whole schedule of prices. Simple inclusion of price indices in a demand equation requires that households be in different market segments.

Numerous approaches have been employed to deal with one or more of these difficulties. Some examples include:

(i) Assume intra-metropolitan price variation does not exist so that all variation in expenditures reflects variations in quantities; use expenditures in demand analysis as an index number to measure quantities. (Muth).

(ii) Allow intra-metropolitan prices to vary across neighborhoods; estimate neighborhood based price indices; then estimate demand equations assuming that residents of each neighborhood face only the prices in their own neighborhood. (King)

(iii) Allow intra-metropolitan prices to vary by individual dwelling units; estimate a dwelling unit price index using a production function for housing and varying input prices; estimate demand equations assuming that occupants of each dwelling unit face only the price of their own dwelling unit. (Polinsky and Elwood)

(iv) Allow the marginal cost of attributes to differ within a metropolitan area; estimate a non-linear hedonic price index and use the first derivative of the index with respect to specific attributes as the price term in a demand equation for the attribute. (Witte, et al)

Each of these approaches has potential shortcomings. Omitting price variation, as in (i), can bias other demand equation parameters if the omitted price term is correlated with included variables. Assuming that households face only their neighborhood or dwelling unit prices, as in (ii) and (iii), may fundamentally mis-state the price variation in the sample if households are not limited in their choices to specific neighborhoods or dwelling units. If all purchasers face all prices, the price "chosen" may reflect the impact of other household characteristics. Neighborhood-based or dwelling unit-based price variation requires a justification for market segmentation based on those dimensions. Estimating demand equations for specific attributes of housing, as in (iv), may not be relevant if we are really interested in the demand for housing as a composite good.

A relatively simple application of residential location theory suggests an alternative way of incorporating price variation into a demand equation for housing as a composite good. Simple models of residential location theory are essentially based on the precepts of cost minimization. A worker surveys the housing market from his workplace, j, and he typically observes that housing prices , R, decline with distance, d, from his workplace in at least one direction. However, travel costs, t, increase with distance from his workplace. For any given amount of housing, H, he faces a total expenditure on housing, Z, composed of a housing expenditure plus a transport expenditure,

$$Z_j = R_j(d).H + t_j(d). \qquad (1)$$

For quantity H_o the worker can solve for the least cost distance by taking derivatives

$$Z_j' = R_j'(d).H_o + t_j'(d) = 0 \qquad (2)$$

and solving the expression for d_j^*, the optimal distance or location for quantity H_o and workplace j. This least cost distance can be substituted back into equation 1 to calculate the minimum total expenditure for quantity H_o, as

$$Z_j^* = R_j(d_j^*).H_o + t_j(d_J^*). \qquad (3)$$

Consider carrying out this exercise for different workplaces in a metropolitan area. The decline of housing prices with distance, $R_j(d)$, will differ systematically across workplaces, very likely showing steep rates of decline with distance for centrally located workplaces and gradual rates of decline for peripheral workplaces. Travel costs per unit distance may also differ by workplace but in ways that may be difficult to generalize. For example, transit speeds may be higher but transit headways longer at peripheral locations as compared to central locations. As the workplace varies, however, there will be variation in the optimal housing and travel expenditure required for housing quantity H_o. This variation in expense by workplace for a given quantity of housing will be used as a measure of price variation in the housing demand equations estimated here. A price index will be estimated for each workplace zone. Households whose heads work

at a particular workplace zone will face the same housing price index. Households with heads at another workplace will face the price index at their workplace, and so forth. Price.variation will be across workplaces.

If housing prices vary by workplace, it is worth asking why all workers do not try to obtain jobs at the workplace that has the lowest housing price index. Urban economists have long argued that a metropolitan area with multiple workplaces and a price gradient for housing will have to have differential wage levels across workplaces for households to be in equilibrium (Moses). The existence of wage gradients across workplaces thus becomes a necessary condition for the workplace based housing price variation approach taken here.*/

III. HOUSING DEMAND AND WORK PLACE-BASED PRICE VARIATION

In developing a workplace based price index for housing, two possible definitions of the price of housing can be used. Different definitions will alter the specification of the demand equations that we estimate. In one formulation the price of housing will be based only on the housing expenditure and will not include the travel expenditure. In this case the budget constraint will be written

$$Y = P_H H + P_V V + t(d) \qquad (4)$$

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*/Preliminary empirical work indicates that a wage gradient with a peak in the Central Business District does exist in Bogota.

where Y is income; P_H, the price of housing; and P_v, the price of a composite commodity V. In this formulation, the travel expenditure, t (d), is included in the income constraint, and the derived demand equation will be of the form

$$H = f\left[P_H, (Y-t[d])\right] \tag{5}$$

That is, travel costs will have to be subtracted from income in the demand equation. If travel costs are an unknown function of distance, d, then d will be included in the demand equation as a separate variable.

In the second possible formulation the price of housing will be the so-called gross price and will be based on the housing expenditure plus the travel expenditure. In this case the budget constraint will be written.

$$Y = Z_H . H + P_v . V, \tag{6}$$

where Z_H is the gross price term. In this case the travel cost does not enter separately into the budget constraint and the distance term will not appear in the demand equations. However, to implement this second approach one must be able to specify a priori the travel cost function which will be a combination of out of pocket cost and the opportunity cost of travel time. Since not enough information is available for Bogota and Cali to allow us to specify the travel cost function with confidence, the first approach has been implemented here. Therefore, the estimated demand equations will have distance to the workplace in them as in Equation 5, and the workplace based price term will be based on housing expenditure only.

The relevant housing expenditure that will be used to define a price index for a given workplace will be the "efficient" or optimal expenditure implicit in the solution of equations 2 and 3 above. Corresponding to each quantity of housing, H, will be an optimal location or optimal distance, d^*, and an optimal expenditure, $R(d^*).H$. If households are employing the kind of locational calculus embodied in residential location theory, the choices made by households with a head employed at a particular workplace will be at or near the optimal location for that workplace, and their housing expenditure will approximate the optimal expenditure for their workplace and housing quantity.* The relation between housing expenditures and housing quantity for a given workplace can be captured by regressing the observed housing expenditure on measures of housing quantity for households whose heads work at the same work zone. The relation between housing expenditure and housing quantity can then be used to formulate a price index for the given workplace. This procedure can be repeated for each workplace so that price indices can be calculated for each workplace. These workplace-specific price indices then can be used as a price term in demand equations for housing as a composite good.

The specific procedure that has been implemented in this paper can be summarized as follows. We have a sample of M households whose household heads have jobs located at one of J workzones, and there are N_j

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*/ Equation 3 can be solved for the expansion path of expenditures as the quantity of housing increases, as shown in Annex 1.

households associated with workplace j. We know for household i ($i = 1$ to N_j) at workplace j the monthly expenditure on housing (or the dwelling unit value), R_{ij}, and a set of K dwelling unit characteristics, X_{ijk}. For each of the J workzones we estimate the equation

$$R_{ij} = \sum_{k=1}^{K} B_{jk} \cdot X_{ijk} \tag{7}$$

by regressing housing expenditure on the measure of dwelling characteristics, and we obtain J sets of parameters which indicate how the cost of housing attributes varies by workplace. We then define a representative dwelling unit in the housing market as the unit that has the sample wide average amount of each dwelling unit characteristic, where the average quantity is

$$\bar{X}_k = \frac{1}{M} \sum_{j=1}^{J} \sum_{i=1}^{N_j} X_{ijk}. \tag{8}$$

The dwelling with attributes $\bar{X}_k$ then becomes the standard unit or the equivalent of the standardized market basket for housing. For each workplace we use the estimated parameters in equation 7 to calculate the cost of the standard unit as

$$\bar{R}_j = \sum_k B_{jk} \cdot \bar{X}_k. \tag{9}$$

This cost of a standardized unit is used to formulate a workplace price index by choosing workplace 1 as a numeraire and calculating a price index

$$\Pi_j = \frac{\bar{R}_j}{\bar{R}_1} \tag{10}$$

The households in the sample also have C household characteristics, HC_c, associated with them that affect household demand for housing. These characteristics of the households and the distance from home to

work, d_{ij}, are used in a demand equation whose dependent variable is housing expenditure divided by the price index in equation 10, or a quantity index of housing. The demand equation is of the form

$$\frac{R_{ij}}{\Pi_j} = f\,(\Pi_j,\ HC_{ijc},\ d_{ij}) \qquad (11)$$

and is estimated over the sample of all M households as a single pooled demand function. In this paper both linear and double log specifications are used for equation 11.

IV. THE SETTING AND THE DATA

The household interview data used to implement the housing demand procedure just outlined are from Bogota and Cali, Colombia. The major data set used was collected in 1978 and covers both owners and renters, for whom equations are estimated separately, in both Bogota and Cali. A second data set is available for Bogota in 1972 but data for only renters can be used to estimate the demand for housing in 1972.

In 1978 Bogota had a population of roughly 3.5 million and Cali, a population of roughly 1.1 million. Both cities have experienced rapid rates of population growth in the past, e.g. Bogota's population in 1972 was 2.8 million, but current population growth rates are moderating in both cities. Per capita income in 1978 was about $800 per annum in the two cities. The cities differ significantly in climate because of their differences in altitude. Bogota is 8000 feet above sea level and has temperate weather with cool nights. Cali, at 3000 feet above sea level, is semi-tropical and warmer than Bogota. Differences in size and climate may well explain some of the differences in housing demand in the two cities.

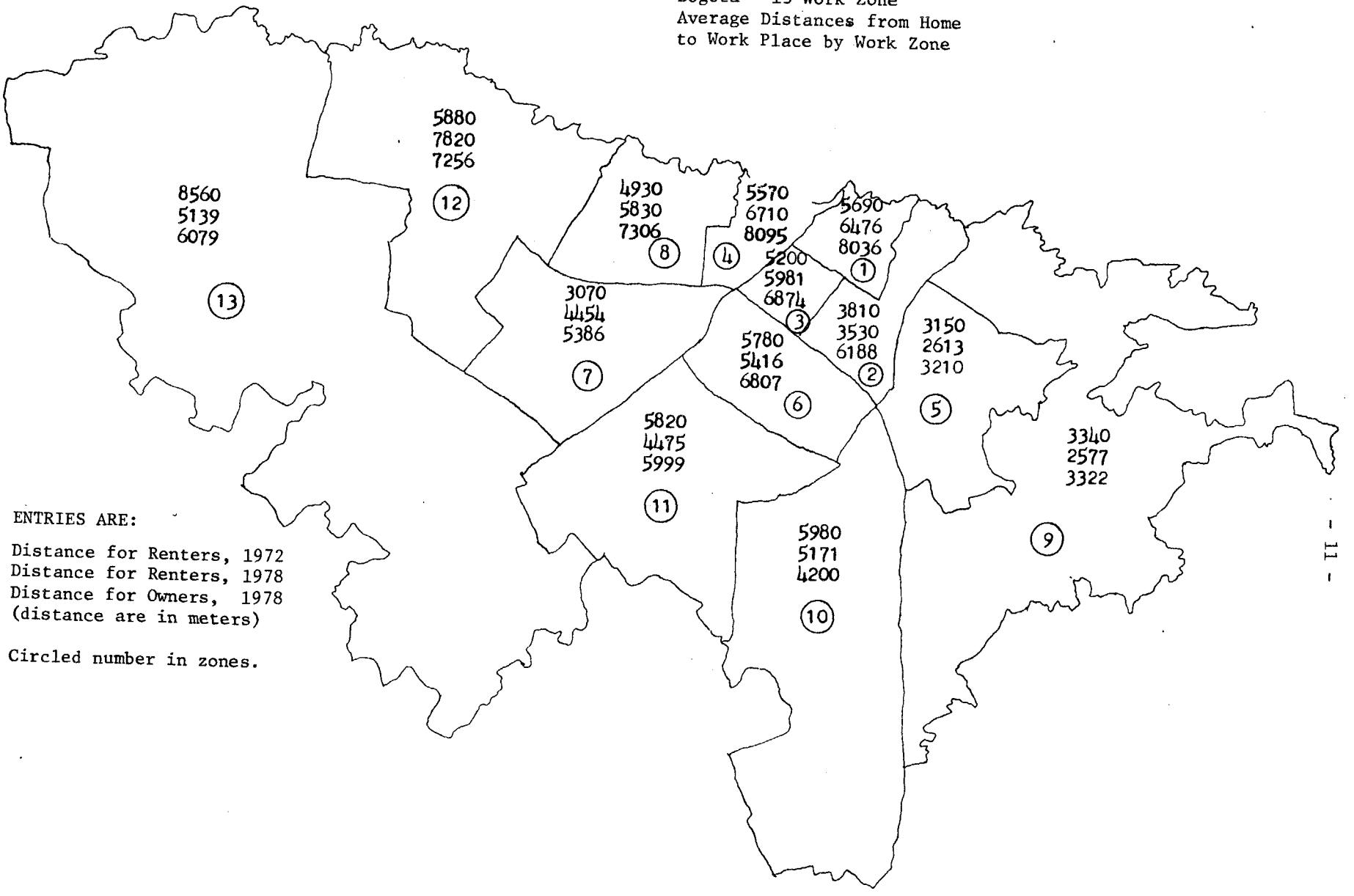
To implement the workplace-derived price indices it was necessary to divide the two cities into a number of workzones. The work zones that resulted are arbitrary but are based on considerations including compactness, respect for significant internal boundaries, and a requirement that there be an adequate number of observations in each work zone. The same work zone system was used in Bogota in 1972 and 1978 and the same work zone system was used for renters and owners in each city. Tabulations of residence and workplace by annular ring and radial sector indicate a high degree of association between place of work of the household head and place of residence of the household. Empirical analyses indicate that the workplace of secondary workers may have a slight influence on a households' residential location, but the workplace of the household head is clearly a dominant determinant of residential location (Pineda). Average commute lengths in kilometers for each work zone and tenure type are shown in Exhibit 1 for Bogota and Exhibit 2 for Cali. In both cities these averages differ by up to a factor of 3. In both cities commute lengths are long for centrally located workplaces and also for workplaces located along the mountains.

V. THE HEDONIC PRICE EQUATIONS

Separate hedonic equations were estimated for each work zone and tenure type in Bogota and Cali in 1978. For 1972 in Bogota a Hedonic equation was estimated for renters only because no data were available about the value of owner occupied units in the1972 sample. For renters the dependent variable is the monthly rent and for owners the dependent variable is the value of the dwelling unit in thousands of pesos. The

EXHIBIT 1

Bogota - 13 Work Zone
Average Distances from Home
to Work Place by Work Zone



ENTRIES ARE:

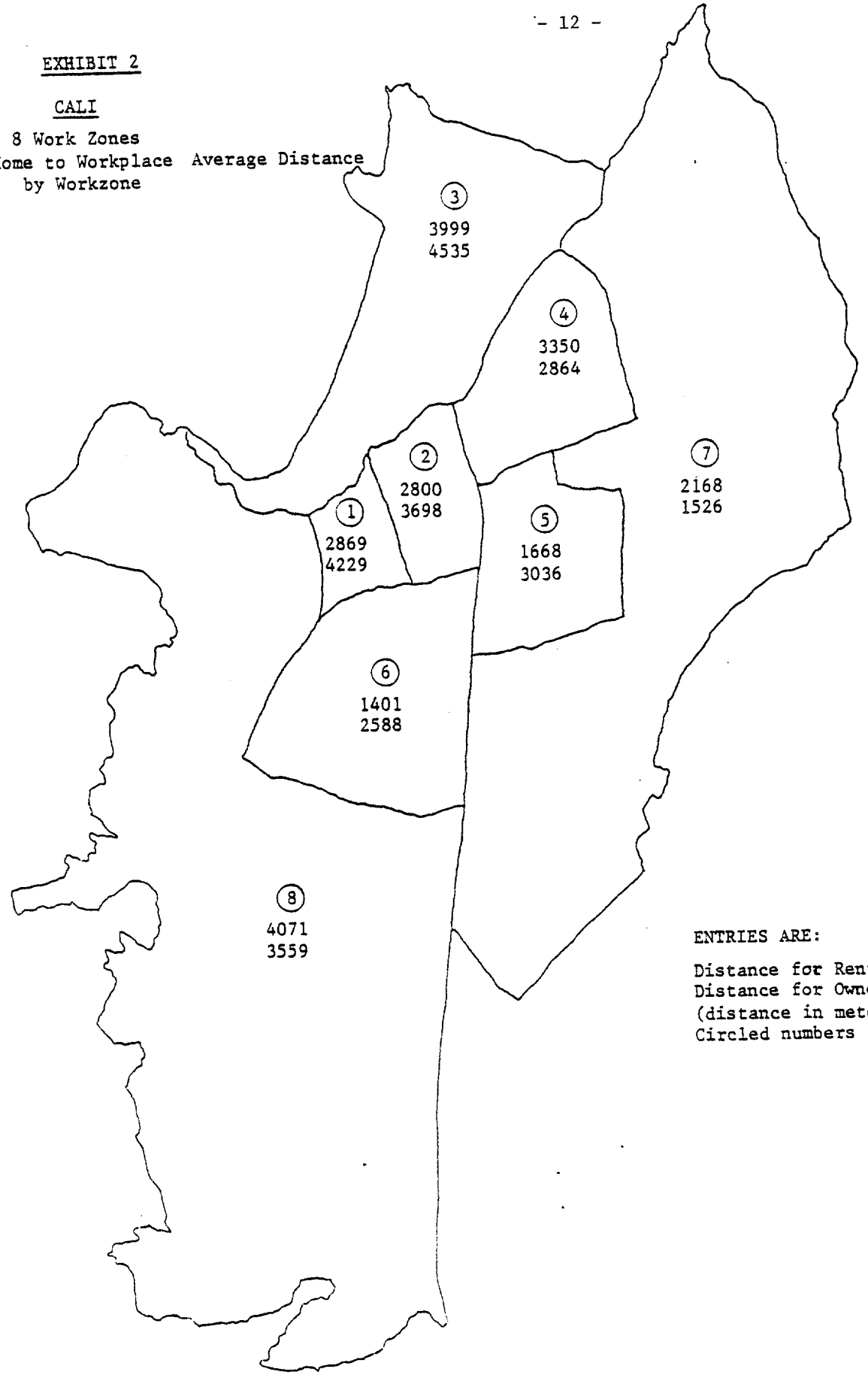
Distance for Renters, 1972
Distance for Renters, 1978
Distance for Owners, 1978
(distance are in meters)

Circled number in zones.

EXHIBIT 2

CALI

8 Work Zones
Home to Workplace Average Distance
by Workzone



ENTRIES ARE:

Distance for Renters, 1978
Distance for Owners, 1978
(distance in meters)
Circled numbers are zones

1978 data were all collected in the same survey with the same questionaire so it is possible to use the same specification for the four sets of 1978 equations. In the 1978 equations the independent variables used included the dwelling unit area in square meters, DUAREA; the lot area in m^2, LOTAREA; the number of blocks to the nearest bus line, BLKTOBUS; a dummy variable equal to 1 if the residence had a private or public phone, DPHONACSS; a dummy variable equal to 1 if the dwelling unit had its own non-shared kitchen and bathroom facilities, DEXCLUSE; and a dummy variable equal to 1 if the dwelling unit had its garbage picked up by municipal authorities, DGARBCOL. The average values for the dependent and independent variables for the 1978 data are shown in Exhibits 3 through 6. It is interesting to note the similarities and differences between tenure classes and cities in these exhibits. Renters in Bogota and Cali, for example, have similar sized units on similar sized lots but Bogota renters have more phones while Cali renters have better garbage collection. Bogota owners have larger, more expensive homes on larger lots than Cali owners. Between renters and owners the most striking differences are in the average area of the unit and the proportion of units having exclusive bath and kitchen facilities; owners are better housed than renters. Finally, there is more variability in the average dependent variable across work zones than there seems to be in the average independent variables.

The independent variables used in the 1972 equations differ from those used in 1978 because the questionaire was quite different. The definition of the 1972 variables and their mean value by work zone

EXHIBIT 3

HEDONIC PRICE ESTIMATION - MEAN VALUES

BOGOTA RENTERS

1978 Household Survey

Variables	All Work Zones	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12	Zone 13
DUAREA	67.75	72.76	70.91	62.79	87.68	71.28	69.74	74.37	71.26	42.47	54.99	64.86	68.50	61.49
LOTAREA	125.20	104.20	141.85	140.00	104.34	111.75	114.67	116.83	117.05	136.47	135.16	144.85	133.15	143.68
BLKTOBUS	1.84	1.68	1.60	1.77	2.05	1.93	1.64	1.57	1.56	1.88	1.74	1.98	2.38	2.31
DPHONACSS	0.58	0.66	0.56	0.56	0.65	0.59	0.59	0.67	0.66	0.41	0.47	0.59	0.54	0.48
DEXCLUSE	0.43	0.51	0.37	0.41	0.60	0.38	0.42	0.46	0.38	0.37	0.38	0.39	0.49	0.32
DGARBCOL	0.54	0.49	0.51	0.56	0.68	0.62	0.62	0.49	0.60	0.37	0.35	0.60	0.58	0.55
MEAN RENT	2104.36	2606.86	2218.67	1928.57	2948.00	1758.52	1873.26	2050.00	2284.07	1277.55	1618.88	1986.02	2307.36	1768.56
HEDONIC PRICE INDEX	2104	2358	2147	1964	2485	1735	1763	1906	2301	1972	1818	2139	2333	1973

EXHIBIT 4

HEDONIC PRICE ESTIMATIONS - MEAN VALUES

BOGOTA OWNERS

Variables	All Work Zones	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12	Zone 13
DUAREA	172.84	212.69	239.75	182.02	183.57	160.70	160.84	172.75	165.07	129.26	147.21	140.26	169.32	145.06
LOTAREA	150.19	168.08	116.18	130.76	153.12	153.70	140.38	137.87	160.16	158.63	134.96	143.42	176.62	153.29
BLKTOBUS	1.90	1.70	1.61	1.80	1.87	1.86	2.27	2.04	1.81	1.75	2.25	2.03	1.76	1.98
DPHONACSS	0.65	0.83	0.51	0.78	0.75	0.57	0.59	0.79	0.65	0.46	0.62	0.57	0.59	0.55
DEXCLUSE	0.84	0.91	0.84	0.88	0.94	0.75	0.83	0.79	0.82	0.80	0.74	0.83	0.84	0.84
DGARBCOL	0.52	0.64	0.35	0.51	0.58	0.57	0.52	0.43	0.59	0.43	0.38	0.54	0.57	0.47
MEAN VALUE	626.96	892.76	393.92	638.55	851.34	484.64	574.84	577.92	693.65	301.48	380.55	484.03	918.41	511.76
HEDONIC PRICES INDEX	627	699.2	436.8	632.6	744.7	533.1	591.8	562.4	705.3	428.0	450.8	552.8	950.1	607.5

EXHIBIT 5

HEDONIC PRICE ESTIMATIONS - MEAN VALUES

CALI RENTERS

Variables	All Work Zones	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
DUAREA	65.35	60.41	56.47	54.00	77.32	73.07	61.58	63.74	76.08
LOTAREA	126.97	129.34	95.40	99.69	163.57	123.52	188.50	107.84	127.00
BLKTOBUS	1.34	1.39	0.85	1.92	1.00	1.41	1.21	1.50	1.42
DPHONACSS	0.20	0.20	0.12	0.19	0.25	0.17	0.25	0.24	0.16
DEXCLUSE	0.41	0.48	0.32	0.42	0.50	0.38	0.33	0.45	0.39
DGARBCOL	0.83	0.89	0.88	0.88	0.93	0.76	0.75	0.76	0.76
MEAN RENT	1805.11	1949.09	1835.29	1585.58	2167.86	2044.83	1781.25	1407.24	1724.34
HEDONIC PRICES INDEX	1805	1890	2167	1703	1974	1944	1858	1412	1631

EXHIBIT 6

HEDONIC PRICE ESTIMATION - MEAN VALUES

CALI OWNER

Variables	All Work Zones	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
DUAREA	124.87	158.32	137.60	140.11	105.00	112.78	149.80	98.74	93.46
LOTAREA	129.08	135.51	144.08	135.34	125.30	105.56	147.90	119.59	119.40
BLKTOBUS	1.58	1.59	1.08	1.54	1.12	1.74	1.60	1.41	2.43
DPHONACSS	0.24	0.32	0.20	0.34	0.15	0.26	0.33	0.06	0.26
DEXCLUSE	0.80	0.95	0.84	0.94	0.82	0.56	0.87	0.47	0.86
DGARBCOL	0.74	0.83	0.68	0.83	0.82	0.59	0.83	0.74	0.54
VALUE	361.49	558.17	467.40	511.63	270.00	243.52	398.83	186.47	220.57
HEDONIC PRICES	361.5	408.1	488.2	402.2	270.1	310.4	259.3	276.9	262.0

are shown in Exhibit 7. These variables are difficult to compare with those used in 1978, but there are some obvious similarities in the spatial distribution of rents and services. Current prices are used in both time periods, and the consumer price index approximately tripled from 47 in 1972 to 150 in 1978.

The coefficients from the hedonic price equations are shown in Exhibits 8 through 12. Again, the 1978 results are the most comparable. In 1978 there are equations for 13 Bogota and 8 Cali work zones and for 2 tenure types, or a total of 42 equations. The only variable that always has the correct sign in all 42 equations is dwelling unit area. Access to a phone, exclusive bath and kitchen facilities, and garbage collection also perform well, having the expected sign 36, 37, and 32 times respectively. The number of blocks to a bus is only positive half of the time, but it is possible that there is some disamenity associated with being too close to the nearest bus route. Lot area does not perform well in the hedonic equations, and it does very poorly in Cali where owners in particular do not seem to value additional lot size. The hedonic equations for the 1972 Bogota renters, shown in Exhibit 12, are similar to those for 1978 in that the measure of interior space, the number of rooms, has a positive effect on rent.

A measure of the explanatory power of the hedonic price equations is shown in Exhibit 13 which summarizes the explanatory power of the regression equations and the workplace stratification in an analysis of variance framework. Overall the analysis explains from 45 to 69 percent

EXHIBIT 7

HEDONIC PRICE ESTIMATION - MEAN VALUES

BOGOTA RENTERS

1972 Household Survey

Variables	All Work Zones	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12	Zone 13
BLDGAGE	16.6	16.88	20.97	18.88	18.58	15.94	15.11	12.51	18.98	13.63	13.00	14.57	14.97	13.79
ROOM	2.48	2.68	2.52	2.17	2.85	2.40	2.27	2.34	2.78	2.00	2.38	2.30	2.46	2.39
SQROOM	8.65	10.05	8.20	6.25	11.81	8.12	7.18	7.61	10.69	5.69	7.64	6.73	9.54	7.61
GARBAGE	1.08	1.04	1.05	1.08	1.05	1.07	1.11	1.07	1.07	1.19	1.09	1.11	1.11	1.06
DISTBUS	144.93	144.59	131.50	135.71	132.72	110.08	145.79	142.92	137.80	165.25	186.63	168.24	141.20	158.89
DHOUSE	0.41	0.39	0.52	0.31	0.46	0.39	0.36	0.43	0.45	0.42	0.41	0.47	0.38	0.41
DAPT	0.24	0.28	0.21	0.30	0.27	0.23	0.26	0.19	0.27	0.18	0.26	0.22	0.14	0.18
DDILAP	0.08	0.09	0.08	0.08	0.02	0.06	0.05	0.09	0.07	0.10	0.09	0.04	0.09	0.06
DDETER	0.28	0.25	0.29	0.27	0.25	0.31	0.33	0.25	0.23	0.34	0.31	0.36	0.26	0.30
DOTHERLU	0.80	0.84	0.69	0.81	0.90	0.65	0.88	0.81	0.83	0.71	0.74	0.84	0.78	0.88
DPUBLI	0.04	0.03	0.04	0.01	0.00	0.04	0.05	0.04	0.06	0.08	0.10	0.03	0.06	0.02
DPRIVA	0.42	0.48	0.51	0.51	0.48	0.42	0.35	0.42	0.50	0.20	0.30	0.24	0.40	0.41
MEAN RENT	862.61	1016.89	881.00	858.12	1067.59	735.28	616.84	689.38	1190.55	516.53	619.48	682.09	951.85	817.50
HEDONIC PRICE INDEX	863	918	850	883	1056	696	669	659	982	676	526	708	1126	755

Note: Variable definitions shown on next page.

EXHIBIT 7 (continued)

Variable Definitions for Exhibit 7

BLDGAGE:	Building age in years.
ROOM:	Number of rooms.
SQROOM:	Number of rooms squared.
GARBAGE:	1 = garbage collection, 2 = mo. garbage collection.
DISTBUS:	Distance to nearest bus line in meters.
DHOUSE:	Dummy variable 1 = unit is house.
DAPT:	Dummy variable 1 = unit is apartment.
DDILAP:	Dummy variable 1 = unit is in dilapidated condition.
DDETER:	Dummy variable 1 = unit is in deteriorated condition.
DOTHERU:	Dummy variable 1 = building also has non-residential use.
DPUBLI:	Dummy variable 1 = unit has public phone.
DPRIVA:	Dummy variable 1 = unit has private phone.

EXHIBIT 8

ESTIMATIONS OF THE HEDONIC PRICE - EQUATIONS

BOGOTA RENTERS
1973

Variables	All Work Zones	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12	Zone 13
CONSTANT	130.31	-40.83	-231.02	238.42	-1505.18	617.41	1377.30	872.59	376.82	323.67	57.44	833.00	-436.22	699.52
DUAREA	15.59	14.02	25.47	10.26	9.58	12.75	8.23	4.66	13.52	21.14	26.54	23.78	22.43	13.84
F-ratio	(239.08)	(19.00)	(37.94)	(9.17)	(4.7)	(57.89)	(18.16)	(4.2)	(17.5)	(21.51)	(28.42)	(30.15)	(23.01)	(28.70)
LOTAREA	1.30	0.965	1.41	1.553	9.46	-0.15	-2.98	0.635	-4.41	-1.93	4.77	-2.27	5.26	-0.305
F-ratio	(4.30)	(0.30)	(0.36)	(0.84)	(10.16)	(0.01)	(2.56)	(0.15)	3.17)	(2.21)	(6.48)	(0.92)	(4.43)	(0.05)
BLKTOBUS	152.99	36.11	-38.36	-192.18	156.25	-43.86	-306.76	-165.46	310.66	17.09	-183.30	-56.83	-111.85	-94.42
F-ratio	(2.18)	(0.07)	(0.05)	(1.90)	(0.84)	(0.39)	(10.07)	(2.87)	(4.56)	(0.05)	(2.12)	(0.12)	(0.93)	(2.51)
DPHONACSS	656.46	904.05	272.97	722.62	1908.01	-199.02	552.12	507.71	560.46	533.46	-38.91	171.73	1169.99	596.69
F-ratio	(23.69)	(3.59)	(0.27)	(3.47)	(6.80)	(0.79)	(3.41)	(2.06)	(1.25)	(4.94)	(0.01)	(0.11)	(3.07)	(3.60)
DEXCLUSE	941.69	1595.70	442.79	1094.12	1846.87	774.51	1017.27	1236.86	1482.85	-134.78	-249.63	338.27	530.18	98.13
F-ratio	(37.66)	(10.25)	(0.38)	(4.88)	(5.97)	(8.92)	(8.14)	(12.62)	(6.84)	(0.19)	(0.26)	(0.36)	(0.51)	(0.05)
DGARBOCOL	127.43	103.35	367.79	562.12	-51.34	255.76	16.95	221.38	58.42	323.21	-314.66	-299.19	-204.71	295.77
F-ratio	(1.00)	(0.06	(0.48)	(1.98)	(0.01)	(1.13)	(0.00)	(0.47)	(0.02)	(1.46)	(0.69)	(0.34)	(0.09)	(0.97)
ADJ R^2	0.4241	0.3471	0.6101	0.4752	0.5029	0.6748	0.5632	0.4458	0.4468	0.4265	0.4899	0.3713	0.3817	0.5017
No. OBS.	1025	156	75	70	65	61	69	63	91	49	89	88	72	77

EXHIBIT 9

ESTIMATION OF THE HEDONIC PRICE EQUATIONS

BOGOTA OWNERS (1978)

Variables	All Work Zones	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12	Zone 13
CONSTANT	-370.84	-604.17	-48.76	-462.58	-287.52	65.25	-463.18	-177.40	-148.96	-123.39	-18.19	-486.19	-795.87	-179.80
DUAREA	1.097	1.08	0.150	0.288	3.266	1.505	0.869	0.926	2.148	3.585	1.605	0.704	2.071	3.522
F-ratio	(45.52)	(5.44)	(0.86)	(0.33)	(8.32)	(8.49)	(1.73)	(1.31)	(8.01)	(37.19)	(6.51)	(0.60)	(2.50)	(14.09)
LOTAREA	1.822	2.73	0.947	1.643	-0.075	-0.060	0.864	1.387	0.907	-0.139	-0.063	2.815	1.506	0.859
F-ratio	(109.21)	(31.93)	(4.46)	(4.57)	(0.00)	(0.01)	(0.99)	(4.27)	(3.69)	(0.27)	(0.01)	(16.45)	(2.77)	(1.36)
BLKTOBUS	18.66	1.89	-39.83	145.63	-46.93	-11.39	89.27	-2.900	38.62	2.292	-0.688	8.655	166.00	12.17
F-ratio	(2.44)	(0.00)	(1.93)	(6.87)	(0.56)	(0.09)	(3.14)	(0.01)	(1.70)	(0.01)	(0.00)	(0.05)	(3.76)	(0.14)
DPHONACSS	309.82	182.59	147.64	259.97	252.83	273.43	432.58	260.77	121.02	-183.73	157.70	333.47	642.27	154.44
F-ratio	(42.25)	(1.11)	(2.21)	(1.46)	(0.92)	(4.10)	(5.85)	(2.05)	(0.63)	(3.99)	(1.94)	(5.49)	(5.85)	(1.07)
DEXCLUSE	273.45	535.00	310.14	378.71	374.12	73.45	339.66	340.35	201.88	61.38	20.09	237.87	462.90	83.91
F-ratio	(22.61)	(5.27)	(5.87)	(1.75)	(0.79)	(0.28)	(2.63)	(4.14)	(1.40)	(0.43)	(0.03)	(2.58)	(2.43)	(0.17)
DGARBOCOL	127.22	252.76	67.78	65.06	168.13	65.25	70.79	-152.81	47.06	32.18	157.65	114.59	72.23	-277.40
F-ratio	(8.59)	(3.68)	(0.42)	(0.12)	(0.65)	(0.00)	0.18)	(1.11)	(0.14)	(0.16)	(2.51)	(1.00)	(0.09)	(3.14)
ADJ R^2	0.3560	0.4290	0.1770	0.2696	0.2743	0.3126	0.2846	0.2221	0.3368	0.5252	0.2091	0.4937	0.4891	0.3812
No. OBS.	838	129	51	51	67	44	64	53	74	46	73	72	63	51

EXHIBIT 10

ESTIMATION OF THE HEDONIC PRICE EQUATIONS

CALI RENTERS

1978

Variables	All Work Zones	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
CONSTANT	475.91	618.44	519.93	131.10	983.85	-469.57	1238.27	1619.87	11185.73
DUAREA	14.07	6.82	13.35	12.93	19.54	22.34	16.61	13.21	11.94
F-ratio	(102.18)	(5.90)	(7.38)	(3.47)	(41.75	(14.70)	(4.27)	(5.03)	(18.78)
LOTAREA	0.4813	0.1635	3.42	1.7039	-0.5709	4.544	-2.556	-3.1275	-4.358
F-ratio	(0.35)	(0.01)	(1.61)	(0.17)	(0.06)	(1.01)	(0.47)	(1.38)	(3.94)
BLKTOBUS	-114.19	-41.91	0.22	116.52	-71.94	-141.16	-461.04	-379.92	-67.31
F-ratio	(4.89)	(0.12)	(0.00)	(0.50)	(0.16)	(0.32)	(3.58)	(8.88)	(0.43)
DPHONACSS	457.67	514.53	1385.18	234.85	-323.58	-284.33	1363.55	1034.76	653.64
F-ratio	(5.44)	(1.37)	(3.53)	(0.09)	(0.47)	(0.13)	(4.57)	(5.01)	(1.58)
DEXCLUSE	288.56	1037.62	17.36	692.80	-545.80	663.77	-686.04	-805.03	758.29
F-ratio	(2.22)	(6.63)	(0.001)	(0.83)	(1.55)	(0.63)	(0.74)	(2.08)	(2.70)
DGARBOCOL	353.23	400.65	75.08	27.16	206.80	418.82	595.65	-42.22	-161.55
F-ratio	(3.24)	(0.66)	(0.009)	(0.001)	(0.07)	(0.30)	(0.73)	(0.01)	(0.13)
ADJ R^2	0.5254	0.4582	0.5440	0.4183	0.7311	0.7224	0.2576	0.2244	0.6325
No. OBS.	261	44	34	26	28	29	24	38	38

EXHIBIT 11

ESTIMATION OF HEDONIC PRICE EQUATION

CALI OWNER

1978

Variables	All Work Zones	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
CONSTANT	-188.88	-244.16	-456.90	-292.86	247.68	-129.24	-514.36	-29.91	50.70
DUAREA	4.00	3.10	6.84	1.36	1.94	1.26	5.31	3.02	1.64
F-ratio	(172.01)	(16.28)	(99.06)	(0.70)	(3.48)	(5.46)	(24.98)	(30.53)	(3.57)
LOTAREA	-1.06	-0.66	-2.52	1.25	-1.38	0.25	-1.27	-0.816	-2.01
F-ratio	(9.93)	(0.42)	(5.89)	(0.62)	(3.27)	(0.12)	(1.09)	(3.19)	(10.50)
BLKTOBUS	21.24	23.01	120.09	21.63	-58.39	25.47	37.83	14.51	-4.89
F-ratio	(2.39)	(0.17)	(4.64)	(0.09)	(1.67)	(1.01)	(0.46)	(0.63)	(0.13)
DPHONACSS	199.67	95.18	349.88	492.92	-11.57	108.96	166.62	84.82	342.20
F-ratio	(15.48)	(0.51)	(2.67)	(5.77)	(0.01)	(1.16)	(1.11)	(1.09)	(20.53)
DEXCLUSE	89.01	135.50	151.74	131.04	7.45	185.22	228.19	4.05	148.30
F-ratio	(3.11)	(0.22)	(0.60)	(0.15)	(0.00)	(5.39)	(1.29)	(0.01)	(3.06)
DGARBOCOL	46.28	248.55	29.24	143.38	65.12	49.17	-9.25	-15.58	99.46
F-ratio	(0.92)	(2.06)	(0.03)	(0.44)	(0.48)	(0.28)	(0.003)	(0.12)	(2.08)
ADJ R^2	0.56304	0.4175	0.8381	0.4058	0.1183	0.5200	0.7107	0.5343	0.6651
No. OBS.	260	41	25	35	33	27	30	34	35

EXHIBIT 12

ESTIMATION OF THE HEDONIC PRICE EQUATIONS

BOGOTA RENTERS - 1972

Variables	All Work Zones	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12	Zone 13
CONSTANT	335.45	380.47	496.30	1172.48	711.64	260.85	671.02	613.87	400.47	270.84	518.59	715.71	-145.41	336.58
BLDGAGE	02.00	01.18	-0.54	-15.09	-6.18	-1.51	3.50	-13.68	-3.65	2.31	-6.60	-0.61	-4.35	-3.82
	(2.15)	(0.17)	(0.02)	(2.79)	(0.65)	(0.09)	(0.92)	(5.12)	(0.47)	(0.34)	(1.79)	(0.01)	(0.34)	(0.37)
ROOM	234.85	202.63	252.19	44.89	716.26	141.58	72.68	214.52	144.22	126.00	-70.01	6.23	578.64	-22.17
	(33.71)	(5.87)	(2.09)	(0.03)	(8.31)	(1.07)	(0.44)	(6.05)	(0.72)	(1.01)	(0.15)	(0.00)	(9.20)	(0.01)
SQROOM	2.04	3.41	-13.66	-8.81	-54.46	9.74	20.29	4.98	19.09	6.90	47.86	42.66	-35.67	61.01
	(0.15)	(0.11)	(0.25)	(0.07)	(3.46)	(0.29)	(1.79)	(0.20)	(0.83)	(0.12)	(2.71)	(1.88)	(2.54)	(2.30)
GABBAGE	-144.06	-210.76	-320.60	-32.34	-803.85	-9.61	-100.31	-206.02	407.93	133.94	-98.49	-243.25	-253.36	289.89
	(4.94)	(1.32)	(1.12)	(0.01)	(2.94)	(0.00)	(0.44)	(1.73)	(0.02)	(1.49)	(0.24)	(1.22)	(1.10)	(0.76)
DISTBUS	-0.11	-0.31	0.42	-1.35	-0.69	0.17	0.08	-0.11	-0.55	-0.13	-0.11	0.60	0.21	0.91
	(0.77)	(1.42)	(0.71)	(4.61)	(0.56)	(0.15)	(0.06)	(0.12)	(1.08)	(0.29)	(0.11)	(2.18)	(0.10)	(2.50)
DHOUSE	205.97	331.19	-61.88	593.77	101.90	179.40	75.52	92.53	367.14	88.94	323.96	142.10	241.61	230.93
	(20.53)	(11.01)	(0.14)	(3.99)	(0.08)	(1.64)	(0.39)	(0.78)	(2.44)	(0.82)	(4.44)	(0.83)	(1.14)	(.135)
DAPT	212.32	394.26	47.43	544.40	-259.12	144.29	185.73	-133.99	181.27	162.48	246.79	264.10	322.70	77.61
	(17.62)	(14.04)	(0.06)	(2.86)	(0.48)	(10.2)	(2.24)	(1.11)	(0.56)	(1.78)	(2.36)	(.193)	(1.22)	(0.11)
DDILAP	-231.50	-396.94	-106.75	-24.13	-652.93	-26.79	47.27	-334.71	-39.83	-22.09	14.57	-795.89	-54.99	-523.55
	(13.21)	(8.99)	(0.18)	(0.01)	(1.00)	(0.02)	(0.06)	(5.91)	(0.02)	(0.03)	(0.01)	(5.64)	(0.04)	(2.69)
DDETER	-152.15	-189.29	-93.29	293.90	0.88	58.06	-80.73	-34.58	-217.98	-127.78	-0.58	-218.43	-111.92	-306.23
	(14.86)	(4.52)	(0.35)	(1.88)	(0.00)	(0.27)	(0.71)	(0.14)	(1.34)	(1.89)	(0.00)	(2.81)	(0.38)	(3.65)
DOTHERD	-177.57	-96.94	-105.87	-518.42	-204.07	-279.10	-461.96	-162.71	-280.07	19.83	-209.20	-300.10	-44.17	-564.03
	(17.91)	(0.97)	(0.52)	(6.05)	(0.34)	(6.29)	(12.65)	(2.25)	(1.86)	(0.04)	(2.54)	(3.04)	(0.06)	(5.67)
DPUBLI	189.15	77.98	514.21	198.50	-	239.50	-65.79	220.69	327.45	164.77	147.20	202.77	453.75	-83.59
	(5.17)	(0.14)	(2.53)	(0.07)		(0.90)	(0.12)	(1.10)	(0.95)	(1.06)	(0.58)	(0.29)	(1.95)	(0.03)
DPRIVA	451.03	555.24	519.24	583.71	475.49	299.15	117.04	217.93	674.57	276.40	198.53	314.74	580.43	442.08
	(145.01)	(50.61)	(12.83)	(9.47)	(3.98)	(6.79)	(1.53)	(5.76)	(17.41)	(6.22)	(1.88)	(4.71)	(10.14)	(7.36)
ADJ R^2	0.4633	0.4623	0.2924	0.3603	0.4345	0.4321	0.5259	0.5361	0.5303	0.3498	0.4044	0.4283	0.5818	0.5191
No. of Obs.	1637	444	100	77	81	124	95	113	127	118	86	74	108	90

Number in parenthesis are F-ratios.

EXHIBIT 13: ANALYSIS OF VARIANCE: HEDONIC PRICE EQUATIONS

DATA	PERCENT OF VARIATION EXPLAINED BY		
	WORK ZONE STRATIFICATION	EQUATIONS	TOTAL
1972 Bogota Renters	4.7	49.3	54.0
1978 Bogota Renters	2.5	47.6	50.1
1978 Bogota Owners	8.7	36.4	45.1
1978 Cali Renters	1.9	64.3	66.2
1978 Cali Owners	8.0	60.9	68.9

of the variation in housing prices with the equations having much more explanatory power than the workplace stratification. Interestingly, the workplace stratification has much more explanatory power for owner occupied units than for renter occupied units. This is consistent with the empirical regularity that owner occupied units have steeper price gradients in urban areas than do renter occupied units. Hence, workplace location matters more in the owner market than in the renter market.

The "standardized" rents and values obtained by plugging the average renter and owner unit characteristics for Bogota and Cali into their respective workplace hedonic equations are shown in the last row of Exhibits 3 through 7 above. For use in the demand equations these rents and values are transformed into spatial price indices by dividing through by the relevant rent or value for workzone 1, the central business district. The resulting normalized price indices are displayed for Bogota in Exhibit 14 and for Cali in Exhibit 15. There obviously is variation in these price indices across workzones. In both Bogota and Cali there is more variation in the price index for owners (the range covers a factor of 2) than for renters.

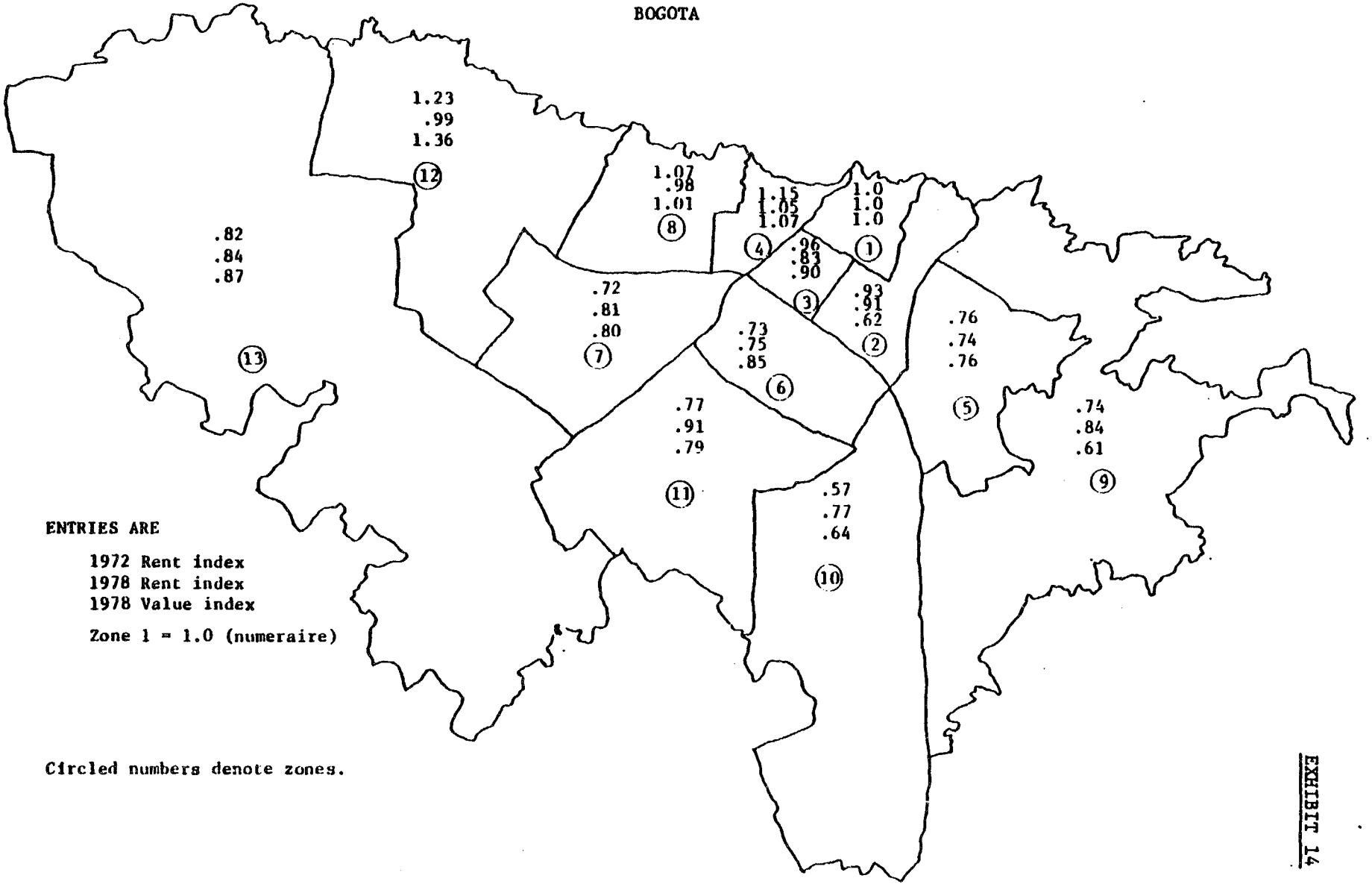
VI. THE HOUSING DEMAND EQUATIONS

The dependent variable in the demand equations is the monthly rent or value divided by the workplace-specific price index as shown in equation 11. The independent variables are monthly household income (a measure of current income) in pesos, the price index described above, and the airline distance from home to work in meters. Three additional

13 WORKZONES

1972 and 1978 Workplace Price Indices

BOGOTA



ENTRIES ARE

1972 Rent index
1978 Rent index
1978 Value index

Zone 1 = 1.0 (numeraire)

Circled numbers denote zones.

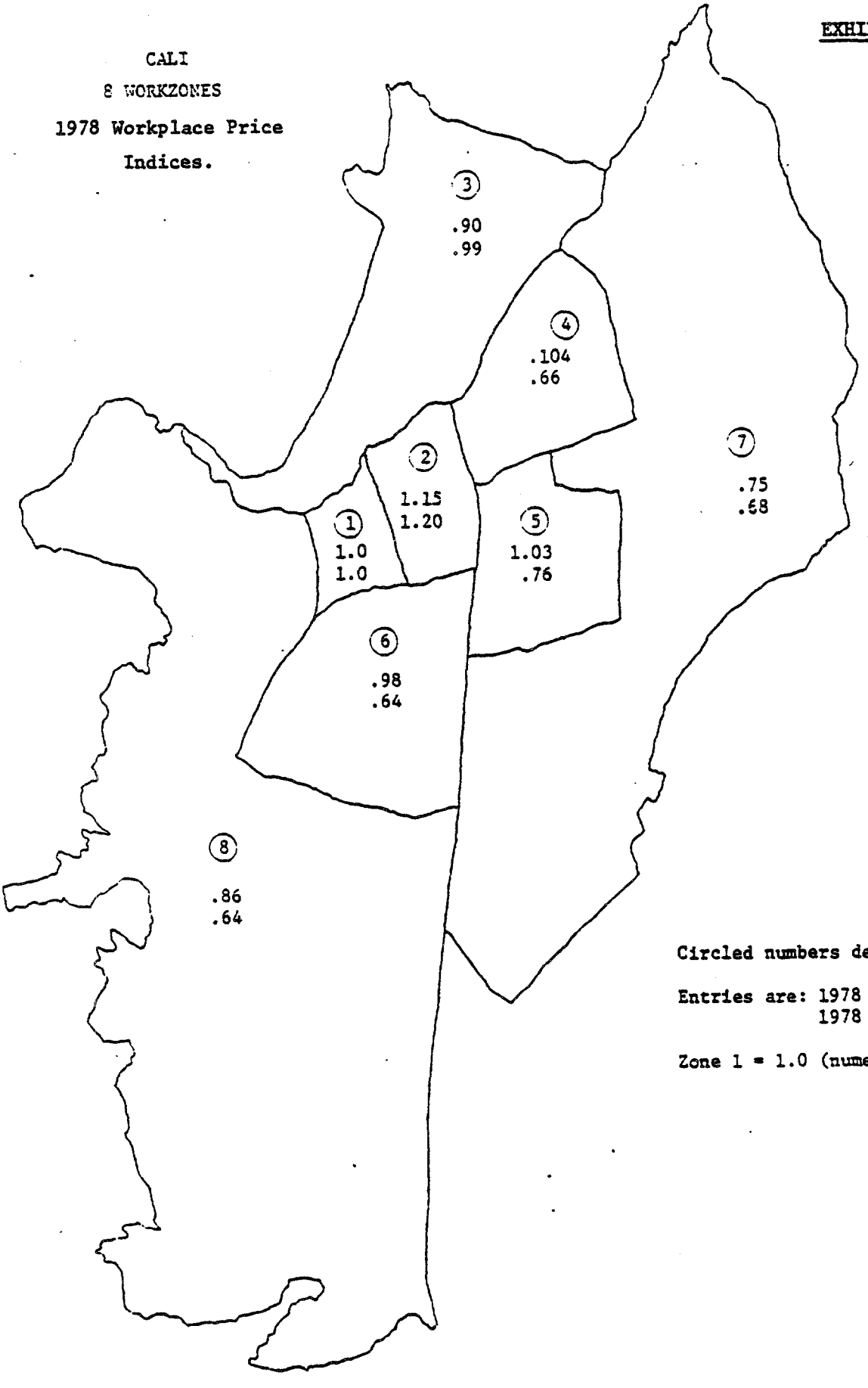
EXHIBIT 14

EXHIBIT 15

CALI

8 WORKZONES

1978 Workplace Price Indices.



Circled numbers denote zones.

Entries are: 1978 Rent index
1978 Value index

Zone 1 = 1.0 (numeraire)

household characteristics are included in the demand equations: a dummy variable for the sex of the household head (1= male); family size measured by the number of persons in the household; and the age of the household head in years. These three characteristics are hypothesized to capture differences in taste (sex of head), differences in the need for housing (family size), and differences in assets or wealth (age of the head). Two functional forms are estimated, double log and linear. In the linear specifications squared terms for family size and the age of the head are entered to capture non-linearity in the effects of those variables.

Five sets of equations are estimated for each year, tenure choice, and city combination. The ten fully specified equations are displayed in column 1 (linear specifications) and column 3 (log-log specification) in the tables in Annex II. Column 5 shows the mean value of each variable in the demand equations. A comparison of these mean values across the five samples shows that renters have younger heads, smaller families, and lower incomes than owners. Differences between Bogota and Cali are slight except for income: Bogota owners have much higher average incomes than Cali owners whereas Bogota renters have average incomes similar to Cali renters. In comparing Bogota renters over time, 1978 Bogota renters had smaller families and younger heads than did 1972 Bogota renters.

The demand equations in Annex II perform well with R^2 statistics ranging from 0.25 to 0.6. Income is by far the most important explanatory

variable. Age of the head and family size are usually significant while sex of the head is usually not significant, although it always has a negative sign. The housing price index is significant in two of the five samples, and it always has the correct sign. Distance from home to work is significant in four of the five samples and has the correct sign in 9 of the 10 equations.

A summary of the fully specified demand equation results are displayed in Exhibits 16 and 17 for renters and owners in the form of of elasticities for each independent variable. These elasticities are calculated in the linear equations using the mean value of each independent variable except income. The linear elasticities are shown for approximately the first, second, and third quartiles of each sample's income distribution. In each case, the sample mean and the 75th percentile of the income distribution are essentially identical.

The magnitude of the various elasticities obviously vary across the samples shown, but they also display a consistent and stable pattern for most of the variables. All income elasticities are less than one, and at the sample mean they lie in a narrow range of 0.6 to 0.8 except for the Cali renter equations. The elasticity of the sex of the head is always negative and small being absolutely less than -0.2. Family size elasticities show an interesting pattern, being negative for owners and usually positive for renters. Since renter occupied units are usually smaller than owner occupied units, it appears that space is a binding constraint for renters, and larger renter families obtain more housing. Owner occupants, on the other hand, seem to be able to reduce the quantity of housing demanded as family size increases because they have larger units

EXHIBIT 16

DEMAND ELASTICITIES AT VARIOUS INCOME LEVELS

RENTERS

Income Pctile	Income Level	Income	Head Sex	Family Size	Age of Head	Price	Home to Work Distance
			1972 - LINEAR - BOGOTA				
25	1000	0.32	-0.16	0.30	0.23	-0.91	-0.05
50	1700	0.45	-0.13	0.25	0.19	-0.75	-0.04
75	3079*	0.59	-0.09	0.18	0.14	-0.55	-0.04
			1972 - LOG/LOG - BOGOTA				
All		0.77	-0.14	0.14	0.12	-0.70	-0.06
			1978 - LINEAR- BOGOTA				
25	3500	0.55	-0.03	-0.24	0.95	-0.17	-0.23
50	7100	0.71	-0.02	-0.16	0.61	-0.11	-0.15
75	11260*	0.80	-0.003	-0.11	0.43	-0.08	-0.10
			1978 - LOG/LOG - BOGOTA				
All		0.72	-0.07	0.10	0.07	-0.28	-0.06
			1978 - LINEAR - CALI				
25	3500	0.05	-0.01	0.48	0.62	-0.34	-0.16
50	7300	0.10	-0.01	0.46	0.59	-0.32	-0.15
75	12829*	0.16	-0.01	0.42	0.55	-0.30	-0.14
			1978 - LOG/LOG - CALI				
All		0.47	-0.20	0.36	0.43	-0.48	-0.03

*Sample Mean.

EXHIBIT 17

DEMAND ELASTICITIES AT VARIOUS INCOME LEVELS

OWNERS

Income Pctile	Income Level	Income	Head Sex	Family Size	Age of Head	Price	Home to Work Distance
			1978 - LINEAR - BOGOTA				
25	6000	0.33	-0.03	-0.34	0.66	-0.31	0.02
50	10900	0.47	-0.02	-0.27	0.52	-0.24	0.01
75	17942*	0.60	-0.02	-0.21	0.40	-0.19	0.01
			1978 - LOG/LOG - BOGOTA				
All		0.78	-0.09	-0.25	0.25	-0.44	-0.02
			1978 - LINEAR - CALI				
25	5000	0.39	-0.06	-0.57	0.53	-0.27	-0.06
50	8800	0.53	-0.05	-0.44	0.18	-0.21	-0.05
75	13841	0.64	-0.04	-0.34	0.13	-0.16	-0.04
			1978 - LOG/LOG - CALI				
All		0.76	-0.06	-0.30	0.08	-0.33	-0.02

*Sample Mean.

on the average, and the quantity of housing is not constrained by family size. Age of the household head has a consistently positive demand elasticity when evaluated at the sample mean. Using the linear demand equation with the squared term for head's age, it is possible to calculate the age at which housing demand is a maximum. This is consistently within the range 50 to 57 except for Bogota owners, for which it is 112. The price elasticity of demand is consistently less than one and becomes absolutely quite small for some of the linear specifications. Finally, the distance elasticity is almost consistently negative and quite small.

Exhibit 18 summarizes the range of demand elasticities obtained from Cali and Bogota and compares them with estimates obtained from household surveys from the United States and Korea. The general pattern of results is quite similar between the U.S. and Colombia, with both countries differing somewhat from Korea. The Colombian income elasticities are somewhat higher than those obtained in the U.S. while the Colombian price elasticities may be lower than those from the U.S. The elasticities of housing demand with respect to family size and age of the head cannot be compared with numbers from the U.S. but are somewhat similar to the Korean estimates. Finally, the effect of the sex of the household head, although usually statistically insignificant in Colombia, is also always negative as in the U.S. There are three possible explanations for this result. First, female headed households may have stronger preferences for housing than male headed households. Second, female headed households may be discriminated against and face higher prices

EXHIBIT 18

RANGE OF HOUSING DEMAND ELASTICITIES
FROM VARIOUS COUNTRIES

(Based on Household Observations)

Country	Elasticity of Housing Demand with Respect to				
	Current income	Price	Family size	Age of head	Sex of head (1 = Male)
			Renters		
Colombia	.2 to .8	-.1 to -.7	-.1 to .4	.1 to .6	-.01 to -.2
USA[1]	.1 to .4	-.2 to -.7	?	?	consistently negative
Korea[2]	.12	-.06 to .03	.15 to .25	-	-
			Owners		
Colombia	.6 to .8	-.15 to -.40	-.2 to -.35	.1 to .4	-.02 to -.1
USA[1]	.2 to .5	-.5 to -.6	?	?	negative
Korea[2]	.21	-.05 to .07	-.02 to .15	-	-

1. From Stephen K. Mayo (1981)

2 From J. Follain et.al. (1980)

which could produce larger expenditures on housing. Those larger expenditures could show up as a preference for larger quantities in the demand equations for renters, but the discrimination hypothesis is unconvincing for owner occupants. Third, female household heads have shorter commute distances than male household heads and may therefore systematically pay higher prices for housing because they commute less far down the rent gradient. The demand equations used should account for this, however, because distance is included. Accordingly, the first explanation, based on preference differences, may be the most plausible.

In order to investigate the effect of distance on the sex of head coefficient, and to see how sensitive the other parameters were to both the price and distance terms, the housing demand equations were estimated without the price and distance terms. The results are shown in columns two and four in the tables in Annex II. Examination of these tables indicates that omitting the price and distance terms tends to reduce the income coefficient very slightly, often only in the third significant digit. The family size effects are also minimally affected by the omission of these two terms. The sex of head and age of head coefficients do change quite a bit in percentage terms, however. This seems to be largely due to the omission of the distance term. Female headed households live closer to the head's workplace than do male headed households, as do households with older heads as compared to households with younger heads. In general, however, the parameter estimates for the included variables are very stable with respect to the omission of the price and distance terms.

These exercises suggest that neither the housing prices as specified in these demand equations nor the distance from home to work are collinear with household income. Indeed, in Bogota and Cali, as in many other cities, the use of micro data dramatically reduces problems of multi-collinearity in the estimation of housing demand equations.

VII. AGGREGATE ESTIMATES OF INCOME ELASTICITIES

All of the parameter estimates that have been presented so far have been obtained from computer based multivariate regressions using individual households as observations. In many situations it may not be possible to gain access to individual household records because of confidentiality restrictions while in other situations sufficient time or adequate computer facilities may make parameter estimation with micro data impossible. In this section we briefly investigate the adequacy of parameter estimates that could be estimated from published aggregated data. We focus on the estimation of the income elasticity of the demand for housing because that parameter is often of interest in both the design and evaluation of housing programs,policies, and projects.

Each of the five samples we have analyzed was summarized in a matrix dimensioned by rent or value and income. Eight income categories were used for the 1978 data and nine for the 1972 data. The average rent or value was calculated for each income category; this average was then regressed on the mid-points of the income

categories in a log-log specification using a hand held calculator. The equations resulting from this exercise are shown in Exhibit 19, and the resulting income elasticities are compared to those from the disaggregate, fully specified equations in Exhibit 20. The aggregate estimates each differ by less than 20 percent from the disaggregate log-log estimates, and in 4 out of 5 cases the aggregate log-log estimates lie between the linear and log-log disaggregate estimates. It is obvious that aggregate based estimates of income elasticities of the expenditure for housing could be a very good approximation for the income elasticity of demand for housing in the samples used here.

It is important to note, however, that the aggregate estimates obtained are very sensitive to the way in which the underlying micro data are aggregated. Two experiments illustrating this were performed with the 1972 sample of renters. First, the sample was aggregated to the level of 63 zones for the city of Bogota, and average rents and incomes were calculated for each zone. A hand held calculator was then used to calculate a log-log regression of average zonal rent on average zonal income using all 63 observations. The resulting income elasticity, 0.95, was substantially higher than the 0.71 estimate obtained using nine observations from the correctly aggregated sample. A third experiment was then run on the 1972 Bogota data. For this experiment the data in the rent-income matrix were incorrectly aggregated by calculating the average income for each rent category and regressing the rent category midpoints on the mean incomes. This rent stratified approach yielded an income elasticity estimate of 1.36, nearly twice

EXHIBIT 19

HOUSING DEMAND EQUATIONS FROM AGGREGATE DATA

Sample	B_o	B_1	R^2
1972 Phase II Renter	2.92	.71	.99
1978 Bogota Renter	1.54	.79	.99
1978 Cali Renter	12.38	.55	.97
1978 Bogota Owner	9.11	.67	.99
1978 Cali Owner	7.81	.66	.97

Equation of form $\text{Rent} = B_o \text{ Income}^{B_1}$

Income stratification

EXHIBIT 20

COMPARISON OF AGGREGATE AND
DISAGGREGATE INCOME ELASTICITIES
OF HOUSING DEMAND

Sample and specification	Aggregate	Disaggregate
1972 Bogota Renter		
Log-Log	.71	.77
Linear	-	.59
1978 Bogota Renter		
Log-Log	.79	.72
Linear	-	.80
1978 Cali Renter		
Log-Log	.55	.47
Linear	-	.16
1978 Cali Owner		
Log-Log	.66	.76
Linear	-	.64
1978 Bogota Owner		
Log-Log	.67	.78
Linear	-	.60

the 0.71 obtained using an income stratified aggregation procedure. It is obvious that the aggregation bias in estimates of income elasticities can be very large, but that correctly aggregated data can give useful results.

VIII. CONCLUSION

This paper has described and implemented a two step estimation procedure for incorporating price variation in the estimation of demand equations for housing using household survey data from Bogota and Cali, Colombia. The demand equations estimated using this procedure give very significant results for the income elasticity of the demand for housing, with estimates of the income elasticity generally lying in the upper end of the range 0.2 to 0.8. Although the price term in the demand equations gave less significant results, the price elasticity of demand appears to be less than one. There is, however, greater uncertainty about the magnitude of the price elasticity than about the magnitude of the income elasticity. Other household characteristics involved in the demand equations have low demand elasticities, typically less than 0.5 in absolute magnitude. The age of the head has a positive elasticity over most of its range while family size usually has a positive elasticity for renters and a negative elasticity for owners. The demand equations suggest that female headed households consume more housing than male headed households, but this result is rarely statistically significant. Distance from home to work is entered into the demand equations as an

adjustment to income, but it is undoubtedly also representing price variation within the workplace strata that are used as the main representation of price variation. The distance elasticity is small, less than -0.2, and is almost always negative.

Comparisons of elasticity estimates with those obtained from U.S. data sets indicate that the range of the Colombian estimates generally overlaps the range of the U.S. estimates. This similarity of values may seem surprising at first, but is much less so on reflection. Housing is a non-traded good and its price is endogenous to the local economy, reflecting, among other things, local income levels. Perhaps we should be more surprised at the similarities between Bogota and Cali, two cities whose climates differ markedly.

Simple experiments involving the aggregation of the household survey data used to obtain micro data estimates suggest that income elasticity estimates based on correctly aggregated data can be good proxies for estimates based on fully specified models using household observations. At the same time, estimates based on micro data that are incorrectly aggregated can produce estimates of the income elasticity of demand that are badly biased.

ANNEX I. Housing Expenditure and Housing Quantity

The residential location model used has been formulated in the location rent/transport cost trade off mode as a surface of total expenditure as

$$Z\ (H,\ d)\ =\ R(d).H\ +\ t\ (d), \qquad \text{(A1-1)}$$

where R(d) is a rent gradient, H is the quantity of housing, t(d) is a travel cost function, and d is a measure of distance or location. The relevant set of Z(H,d)'s for a household to consider are those where for each H, Z(H,d) is a minimum. These minimum points constitute a locus of efficient expenditure points for a household on a graph whose axes were labelled Z and H. This total expenditure expansion path can obviously be disaggregated into an expenditure expansion path for each of its two-components, transport and housing. We can solve for the housing expenditure expansion path, using general notation, by taking the derivative of Equation A1-1

$$Z'\ (H,D)\ =\ R'\ (d).H + t'(d) = 0 \qquad \text{(A1-2)}$$

and solving for the optimal location, d*, as

$$d^*\ =\ g\ (R',\ t',\ H). \qquad \text{(A1-3)}$$

This can be substituted back into the housing expenditure expression to form an expansion path of housing expenditures as

$$R\ (d^*).H = R\left[g(R^t,\ t'\ H)\right]\ .H, \qquad \text{(A1-4)}$$

which is a function of workplace-specific price gradients and travel costs, as well as the quantity of housing consumed. It is this expenditure expansion path that we are trying to summarize with our workplace-specific price index.

Note that one could substitute a housing demand equation for H into equation A1-3 and get an expression for d* as a function of R', t', and income plus other household characteristics.*/ We have not employed this completely reduced from approach because the goal of this exercise is the estimation of housing demand equations. Hence, we deal only with cost minimization concerns in order to define an efficient consumption possibility locus for a household.

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*/ I owe this point to Joseph DeSalvo.

ANNEX II. Housing Demand Equations

SPECIFICATION OF DEMAND EQUATIONS

The demand equations summarized in the next pages use two different specifications defined as follows:

LINEAR

$$EXP/P_h = Bo + B_1 Y + B_2 P_h + B_3 X + B_4 X^2$$

Demand elasticities vary with independent variables.

LOG/LOG

$$EXP/P_h = B_o \cdot Y^{B1} \cdot P_h^{B2} \cdot X^{B3}$$

Demand elasticities are constant.

NOTATION

EXP = Housing Expenditure (rent or value)

P_h = Housing price index; workplace-specific

Y = Current household income

X = Other household characteristics

B_i = Parameters

Table AII-1

BOGOTA RENTER - 1978

	LINEAR		LOG-LOG		MEAN VALUE OF VARIABLE
Constant	-1461. (1.2)	-2051 (2.3)	0.991 (2.9)	0.367 (1.1)	
Income (pesos/mo)	0.178 (28.3)	0.177 (28.3)	0.721 (26.8)	0.694 (25.0)	11260
Head Sex (1 = male)	-37.3 (0.2)	-60.5 (0.3)	-0.068 (1.1)	-0.097 (1.5)	0.843
Fam. Size	198. (1.5)	172. (1.3)	0.099 (2.3)	0.085 (1.9)	4.29
Fam. Size^2	-24.6 (2.1)	-23.2 (2.0)	-	-	22.9
Head Age	94.2 (2.0)	103. (2.2)	0.068 (0.8)	0.216 (2.6)	34.8
Head Age^2	-0.83 (1.5)	-0.89 (1.6)	-	-	1325
Price	-217 (0.25)	-	-0.278 (1.4)	-	0.891
Distance (Meters)	-0.051 (2.5)	-	-0.060 (9.1)	-	5088.
R^2	0.473	0.469	0.471	0.424	Mean Dep. Var. = 2518
Comp. R^2	0.473	0.469			

Sample Size = 1038

Table AII-2

BOGOTA OWNER - 1978

	LINEAR		LOG-LOG		MEAN VALUE OF VARIABLE
Constant	185. (0.4)	57.3 (0.1)	-1.56 (3.1)	-1.52 (3.1)	
Income	0.024 (17.5)	0.024 (17.6)	0.776 (25.)	0.746 (24.3)	17942
Head Sex (1 = male)	-15.1 (0.2)	-15.8 (0.2)	-0.087 (1.0)	-0.097 (1.1)	0.88
Fam. Size	-21.0 (0.5)	-22.1 (0.5)	-0.254 (4.1)	-0.263 (4.2)	5.68
Fam. Size^2	-0.40 (0.1)	-0.33 (0.1)	-	-	37.5
Head Age	11.2 (0.6)	11.6 (0.6)	0.251 (2.2)	0.299 (2.6)	43.5
Head Age^2	-0.05 (0.2)	-0.06 (0.3)	-	-	1991.
Price	-150.8 (1.1)	-	-0.437 (3.4)	-	0.891
Distance (Meters)	0.0011 (0.2)	-	-0.018 (2.0)	-	6099.
R^2	0.282	0.281	0.442	0.428	Mean Value Dep. Var. = 722
Comp. R^2	0.82	0.281			

Sample Size = 844

Table A11-3

CALI RENTER - 1978

	LINEAR		LOG-LOG		MEAN VALUE OF VARIABLE
Constant	-968. (0.8)	-1744. (1.8)	1.30 (1.9)	0.894 (1.3)	
Income (pesos/mo)	0.024 (5.2)	0.025 (5.3)	0.472 (8.6)	0.468 (8.5)	12828
Head Sex (1 = male)	-26.5 (0.1)	-98. (0.4)	-0.20 (1.6)	-0.21 (1.6)	0.828
Fam. Size	205. (1.3)	159. (1.0)	0.363 (4.3)	0.336 (4.0)	4.08
Fam. Size^2	-0.85 (0.1)	1.81 (0.1)	-	-	21.4
Head Age	118. (2.4)	123. (2.5)	0.429 (2.6)	0.521 (3.3)	34.8
Head Age^2	-1.16 (2.0)	-1.20 (2.0)	-	-	1328.
Price	-587. (0.7)	-	-0.475 (1.3)	-	0.96
Distance (Meters)	-0.104 (2.5)	-	-0.031 (2.2)	-	2551.
R^2	0.243	0.224	0.350	0.334	Mean Val. Dep. Var. = 1874
Comp. R^2	0.243	0.224			

Sample Size = 262

Table AII-4

CALI OWNER - 1978

	LINEAR		LOG-LOG		MEAN VALUE OF VARIABLE
Constant	-57.6 (0.1)	-141 (0.4)	-1.09 (1.1)	-1.31 (1.4)	
Income (Pesos/Mo.)	0.0202 (9.8)	0.0201 (9.9)	0.755 (12.2)	0.737 (12.0)	13,841
Head Sex (1 = male)	-19.1 (0.2)	-26.7 (0.4)	-0.055 (0.4)	-0.087 (0.6)	0.799
Fam. Size	-0.814 (0.0)	-0.543 (0.0)	-0.295 (2.6)	-0.281 (2.5)	5.55
Fam. Size^2	-1.97 (0.6)	-1.91 (0.6)	-	-	36.3
Head Age	16.1 (1.0)	15.9 (1.0)	0.079 (0.4)	0.168 (0.9)	44.9
Head Age^2	-0.154 (0.9)	-0.148 (0.9)	-	-	2156.
Price	-84.5 (0.5)	-	-0.332 (1.4)	-	0.817
Distance (Meters)	-0.005 (0.4)	-	-0.019 (1.)	-	3250.
R^2	0.298	0.296	0.376	0.367	Mean Val. Dep. Var. = 436
Comp. R^2	0.298	0.296			

Sample Size = 259

Table AII-5

BOGOTA RENTER - 1972

	LINEAR		LOG-LOG		MEAN VALUE OF VARIABLE
Constant	440.6 (2.1)	-96.7 (0.5)	0.467 (0.2)	0.066 (0.3)	
Income (Pesos/Mo)	0.180 (41.)	0.176 (40.)	0.770 (44.)	0.754 (42.)	3079
Head Sex (1 = male)	-98.2 (1.9)	-79.5 (1.6)	-0.135 (2.7)	-0.125 (2.5)	0.887
Fam. Size	62.1 (2.7)	63.2 (2.&0	0.143 (4.6)	0.156 (4.8)	5.0
Fam. Size^2	-2.29 (1.3)	-2.6 (1.2)	-	-	31.2
Head Age	14.1 (1.4)	13.2 (1.3)	0.123 (2.2)	0.146 (2.5)	36.3
Head Age^2	-0.133 (1.1)	-0.121 (1.0)	-	-	1432.
Price	-562 (6.1)	-	-0.696 (8.8)	-	0.907
Distance (Meters)	-0.0049 (1.4)	-	-0.062 (4.5)	-	5162
R^2	0.560	0.548	0.595	0.567	Mean Dep. Var. = 932
Comp. R^2	0.560	0.548			

Sample Size = 1561

IX. REFERENCES

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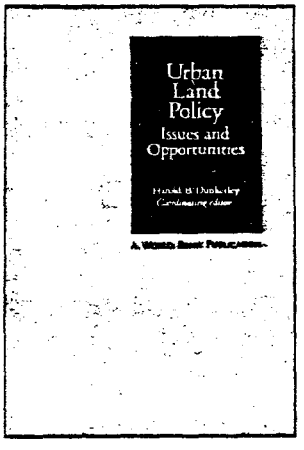

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