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Joint Estimation of the Demand for Attributes

INTRODUCTION

It would be surprising if household demands for the various residential attributes were not interrelated. This likelihood of interdependence suggests the desirability of specifying and estimating some form of simultaneous-equation system that fully embodies it. Unfortunately, our understanding of the precise nature of this interdependence is insufficient to permit specification of a satisfactory multiple-equation model of this kind. Consequently, no fully simultaneous model of the demand for housing attributes is attempted here.

The analysis presented in this chapter deals with a more limited form of simultaneity in housing consumption by recognizing the budgetary interdependence implied by households' decisions to consume attributes. In the analysis that follows, the eighteen housing attributes are combined into four bundle components.

Regression equations relate four composite variables, interpreted either as the quantities of four identifiable bundle components purchased by each household or as household expenditures for these separate bundles, to socioeconomic characteristics through the covariance of the error terms. As Zellner has demonstrated, these "seemingly unrelated regressions," arising from budgetary and other studies of consumer behavior, can be more efficiently estimated by using the residuals obtained from the ordinary least-squares estimates in a two-stage process.[1]

Presumably, it would have been possible to use the same technique to estimate separate expenditure relations for each of the eighteen

[1]Arnold Zellner, "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias," *Journal of the American Statistical Association* 57, no. 298 (June 1962): 348–68.

housing attributes, but the large number of variables and equations would have made the analysis cumbersome, hard to interpret, and a computational nightmare. The attribute prices, presented in Chapter 8, provided a basis for aggregating the individual attributes into a smaller number of homogeneous bundle components.

The price times quantity aggregates defined in the following section have two interpretations. They can be viewed as household expenditures for distinct but related housing attributes. Alternatively, they may be interpreted as measures of housing output, and the total quantity (market price) of housing can be disaggregated into several meaningful components.

DEFINITION OF THE BUNDLE COMPONENTS

The bundle components used in the analyses in this chapter are quite similar to the attribute categories used in Chapters 8 and 9. The principal differences are that parcel area is separated from the dwelling-size variable and is analyzed separately, and several variables (proportion white, miles from the CBD, school quality, and neighborhood crime) are not included in the neighborhood-quality bundle. Parcel area is treated as a separate variable because the ordinary least-squares analysis of the demand for attributes in Chapter 9 clearly indicates that the determinants of demand for exterior space are very different from those for space within the dwelling unit. School quality and neighborhood quality are omitted because we believe that the gains from being able to include suburban observations are greater than the losses occasioned by omission of these attributes from the analysis. Miles from the CBD was omitted because of its low explanatory power in the rent and value equations; the neighborhood racial composition variable is also excluded. The following is a list of the four bundle components and the attributes comprising them.

Dwelling Quality
- Interior condition
- Exterior condition
- Hot water
- Central heating
- Structure age

Interior Space
- Number of rooms (logarithm)
- Number of baths

Neighborhood Quality
- Quality of adjacent units
- Quality of the block face
- Median schooling

Exterior Space
- Parcel area

The dependent variables used in the analysis presented in this chapter are constructed for each sample dwelling unit by multiplying estimates of the market value of each attribute by the quantity of each attribute consumed and combining these products to form the four bundle components. These composite quantities measure the implicit expenditures by each household for each of the four bundle components. Alternatively, they may be considered as measures of four types of housing output provided by each property. The sample used in this analysis is the same as that employed in Chapter 9; it includes all renter units, owner-occupied single detached units, and owner-occupied units located in multifamily structures.

The imputed attribute prices used in forming bundle components are obtained from a modified rental equation for all nonghetto rental properties. These renter prices are used as weights to define the four bundle components for both owner-occupied and renter-occupied dwelling units, and for ghetto as well as nonghetto properties. Since the structures of attribute prices differ between the owner and renter samples, different composite quantities would be obtained if price weights were derived from the owner-value equation, or if these weights were obtained from a different subsample, such as the entire sample or the ghetto. This index number problem could have been circumvented by separate analyses of the renter and owner samples. However, we conclude from our analysis of housing attributes that separation of the sample into owner and renter populations obscures important aspects of household behavior and that a better understanding of the demand for housing services is achieved from analyses of pooled renter and owner samples.

There are several reasons for preferring the price weights derived from the hedonic price index for nonghetto rental properties over various other possible indexes. The prices imputed from ghetto properties are strongly influenced by other manifestations of discriminatory practices in the housing markets. Use of the nonghetto sample insures that the prices will be uncontaminated by these distortions. Use of renter prices provides information on the market value of central heating and hot water, which are important. Price weights derived from the value

equations seem less appropriate for this analysis than those derived from the rental equations because the value weights implicitly include expectations about capital gains (or losses), whereas the rental weights measure the instantaneous flow of services.

An additional reason for using prices derived from the rental sample is that the analysis of Chapter 8 clearly indicates that the presence of hot water and central heating are important determinants of the value of rental units. Implicit prices of these attributes cannot be derived from the owner-occupied sample, since virtually all such units possess both attributes. Unfortunately, use of prices derived from the rental sample neglects the floor-area variable, but this deficiency would manifest itself even if owner prices had been used, since this information does not exist for rental properties. In the final section of this chapter, we present a separate analysis of the demand for single detached units, using bundle components based on owner-occupied attribute prices.

The rental equation used to estimate the attribute price weights is identical to the additive, entire nonghetto equation shown in Table 8-2, except that distance from the CBD, proportion white, and dummy variables for structure type are omitted. Structure type is deleted because there is no reasonable way to assign its influence to a particular attribute bundle, and because it undoubtedly proxies the effects of several of the included attributes. The four bundle components defined by these price weights are shown by Equations 10-1 to 10-4; the relevant t ratios appear in parentheses.

(10-1) Dwelling quality (DQ) = 6.204 Interior condition + 3.648
(2.792) (1.257)
Exterior condition + 5.713 Hot water + 2.061 Central
(0.911) (0.745)
heating − .4267 Age of structure
(−6.186)

(10-2) Interior space (IS) = 28.60 Logarithm of the number of
(6.602)
rooms + 13.28 Number of baths
(2.463)

(10-3) Neighborhood quality (NQ) = 1.705 Quality of adjacent
(0.835)
units + 3.771 Quality of the block face + 3.222 Median
(1.835) (2.891)
schooling

(10-4) Exterior space (ES) = .2127 Parcel area (000's of square feet)
(3.578)

The remaining terms in the modified nonghetto renter equation are:

(10-5) No utilities and furnishings = −6.491 No heat included in rent − 2.266 No water − 7.921 No furniture − 15.72 No major appliances − 5.517 Owner in building − 0.245 Years of occupancy
(−2.331) (−0.771) (−1.733) (−4.370) (−2.332) (−3.200)

(10-6) Constant = −24.62
(−1.433)

These four composite variables are estimates of the monthly cost of each bundle component in the nonghetto rental market. Since the quantities of each bundle component are measured in the same units, dollars of expenditure, they are more easily compared than are individual attributes, which are measured in a variety of units, such as rooms, square feet, and units of physical condition.

Mean quantities (or expenditures) for each bundle component consumed by all sample households, by blacks, and by whites are shown in Table 10-1. Interior space and neighborhood quality are the largest components of housing output or expenditure for all three groups. The mean quantity of dwelling-unit quality is considerably less. For whites, the average amount of dwelling-unit quality consumed is half as large as the mean quantity of neighborhood quality. Blacks, on the average, consume less than one-fourth as much dwelling-unit quality as neighborhood quality. Exterior space accounts for the smallest proportion of total housing output for all four groups. The data in Table 10-1 further indicate that, on the average, white households consume considerably more of each bundle component except dwelling-unit size, the most pronounced differences being obtained for dwelling-unit quality and exterior space.

Interpretation of the quantities of housing attributes summarized in Table 10-1 is not entirely unambiguous. If the price equation is correctly specified, the coefficients for each attribute measure the monthly rental cost of an additional unit of each housing attribute outside the ghetto. For the equation used, however, the sum of the prices and attribute quantities do not exhaust total market value; the equation has a negative intercept, −$24.62. In addition, another $32.40 must be subtracted for the estimated costs of utilities and furnishings. Therefore, the average quantity (value) of housing services consumed, excluding heat, water, appliances, and furniture, is equal to the sum of the composite bundles minus $57.02.

The rather large negative intercept obtained for the price equation

TABLE 10-1
Means and Standard Deviations of Bundle Components for All St. Louis Households, Blacks, and Whites

	All		Blacks		Whites	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Bundle components						
Dwelling quality	19.30	15.85	9.10	12.53	24.52	14.80
Interior space	57.07	15.27	55.03	14.73	58.11	15.43
Neighborhood quality	47.26	7.48	42.21	5.68	49.84	6.95
Exterior space	9.13	25.87	5.42	4.00	11.03	31.50
No utilities or furnishings	−32.40		−32.40		−32.40	
Constant	−24.62		−24.62		−24.62	
Constant plus rent corrections	−57.02		−57.02		−57.02	

suggests that the true relationship between market value and quantities of housing attributes included in the rental equation is nonlinear. As Figure 10-1 suggests, this nonlinearity is so large that the equation actually predicts negative rents for the smallest, lowest-quality, highest-density dwelling units in the worst neighborhoods. There are relatively few such units, but they do exist. Structure age, for example, may have a nonlinear effect upon prices. In addition, as we discussed in Chapter 8, the prices of some types of quality may be related to unit size. Thus, an average rent discount for age or quality may overstate the discount for small structures.

The composite bundles could be adjusted in magnitude to exhaust total housing output, but there are several plausible allocations of the intercept term.[2] One method, which would divide the intercept among the four bundles according to their mean proportions, is illustrated in Equation 10-7 for DQ, where DQ_i^a is the quantity of dwelling quality for a particular sample adjusted for the constant term, DQ_i is the unadjusted quantity, 19.30 is the mean unadjusted quantity of dwelling quality for the entire sample shown in Table 10-6, and the denominator is the sum of the sample means for all four attribute bundles.

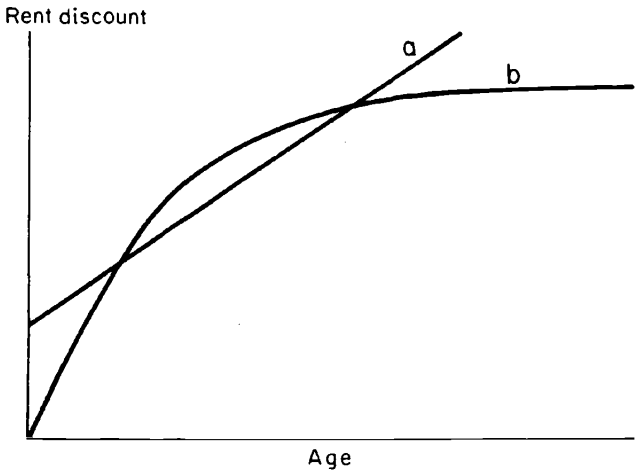

FIGURE 10-1
Estimated Linear and Hypothesized Nonlinear Relationships Between Rent and Structure Age

[2]As an alternative, the price regression could be respecified to suppress the constant term or to introduce nonlinearities directly. Both methods were tried with no less ambiguous results. It is difficult to distinguish the results of nonlinear price relationships from the simple additive model; in equations without intercepts, certain important variables were insignificant or had the wrong sign, again reflecting more complex price relationships.

$$(10\text{-}7) \quad DQ_i^a = DQ_i + \left(\frac{19.30}{19.30 + 57.07 + 47.26 + 9.13}\right) \quad (-57.02)$$

An alternative method would use the proportions for each sample observation as weights. Equation 10-8 illustrates this weighting scheme for DQ.

$$(10\text{-}8) \quad DQ_i^a = DQ_i + \left(\frac{DQ_i}{DQ_i + NQ_i + IS_i + ES_i}\right) \quad (-57.02)$$

Alternative estimates using Equations 10-7 and 10-8 for all households, for blacks, and for whites shown in Table 10-2 illustrate the effect of these different allocation methods on the distribution of housing consumption by attribute bundle.

ESTIMATION OF THE DEMAND FOR BUNDLE COMPONENTS

To estimate the demand for bundle components, we employ a method first suggested by Zellner for systems of equations where disturbances are correlated among equations. Zellner's method provides consistent estimates for systems of equations characterized by intercorrelations among the residuals of individually estimated equations. There are a number of reasons for expecting that the residuals from single-equation estimates of the kind presented in Chapter 9 will be correlated. For example, all of the individual consumption items are subject to an identical budget constraint.

Zellner suggests dealing with these forms of interdependence by estimating the demand equations as a system, using the variance-covariance of the generalized disturbance estimated from a set of ordinary least-squares equations to correct the estimates. This technique does not

TABLE 10-2
Modified Estimates of Bundle Components for All Households, Blacks, and Whites, Using Different Allocations of the Constant Term

	All	Blacks		Whites	
Bundle Components	(I)	(I)	(II)	(I)	(II)
Dwelling quality	11.01	.81	4.46	16.23	14.78
Interior space	32.56	30.52	26.96	33.60	35.02
Neighborhood quality	26.96	21.92	20.68	29.54	30.04
Exterior space	5.21	1.50	2.66	7.11	6.65

NOTE: I. Computed from Equation 10-7. II. Computed from Equation 10-8.

correct for the biases arising from the failure to specify correctly the form of supply or stock interdependence among individual housing attributes. However, it does provide consistent estimates as long as the independent variable set used in estimating the equations differs in at least one of the equations.

The equations for household demand for dwelling and neighborhood quality include no family-size detail for those households with children. In contrast, an elaborate description of the size and composition of families with children is included in the interior space equation. Three variables are included: the number of infants (children under six), the number of children (children six to eighteen), and the number of adults (persons over eighteen).

The exterior-space equation also includes a family-size variable, the number of persons in the family. The head-unemployed and more-than-one-household-member-employed variables were omitted from the interior-space and exterior-space equations. In all other respects, the four equations are identical to the ones appearing in Chapter 8.

In Table 10-3, we present both ordinary least-squares and the more efficient coefficient estimates of household demand for the four attribute bundles. The results for the two methods of estimation are quite similar; therefore, the discussion of findings for all households will be limited to the more efficient estimates.

Findings for the attribute-bundle demand equations shown in Table 10-3 are generally consistent with those presented in previous chapters. Black households consume considerably less neighborhood and dwelling-unit quality, but as much interior space as white households of similar income, educational attainment, labor-force attachment, and family size and composition. The magnitude of these effects is apparent from Table 10-4, which summarizes the effect of changes in each explanatory variable measured as a percentage of the mean of each attribute bundle. The coefficient of the race variable in the dwelling-quality equation, -11.62, is 60 percent of the average amount of dwelling quality consumed by sample households (Table 10-4). Similarly, the race coefficient in the neighborhood-quality equation is 13 percent of the mean consumption of neighborhood quality by sample households. The dummy race coefficient is also negative in the size equation, but its value is less than one-tenth of 1 percent of the mean quantity of dwelling-unit size consumed by sample households, and its t ratio is only .04. The coefficient of the race variable is also negative in the exterior-space equation and is large relative to the mean of parcel area for sample households, but its coefficient is slightly smaller than its standard error.

Because the effects of income and education are so interrelated,

TABLE 10-3
Seemingly-Unrelated-Regression (SURE) and Ordinary-Least-Squares (OLS) Estimates of Bundle Components for All Households

	Dwelling Quality		Interior Space		Neighborhood Quality		Exterior Space	
Variables	SURE	OLS	SURE	OLS	SURE	OLS	SURE	OLS
Race	−11.62[1]	−11.58[1]	−.04	−.02	−5.95[1]	−5.93[1]	−1.56	−1.54
Income	.58[1]	.59[1]	1.06[1]	1.06[1]	.30[1]	.31[1]	1.35[1]	1.35[1]
Education	1.28[1]	1.27[1]	.50[1]	.50[1]	.60[1]	.59[1]	.39[4]	.38[4]
Years on current job	.19[1]	.19[1]	.08[3]	.08[3]	.06[1]	.06[1]	−.05	−.05
Retired	7.08[1]	7.20[1]	.92	.93	2.48[1]	2.62[1]	1.77	1.75
None employed	−2.40[4]	−2.60[4]			−.81[4]	−1.01[4]		
More than one employed	−.43	−.68			−.19	−.29		
Families								
Age	−.01	−.01	.20[1]	.20[1]	.01	.01	.12[3]	.12[3]
Number of persons							−.25[4]	−.30[3]
Number of infants			.83[4]	.70[4]				
Number of children			2.44[1]	2.40[1]				
Number of adults			.19[2]	.17[3]				
Male head	−1.00	−.95	−.11	−.12	.08	.14	.82	.80
Household types								
Single female	1.48[4]	1.48[4]	−3.74[1]	−3.90[1]	−.31	−.30	−2.69[4]	−2.86[4]
Single male	−4.34[1]	−4.35[1]	−4.44[1]	−4.59[1]	−1.95[1]	−1.94[1]	−4.14[4]	−4.26[4]
Couple	2.05[3]	2.05[3]	−3.88[1]	−4.04[1]	−.02	−.02	−4.42[2]	−4.57[2]
Constant	4.56[2]	4.62[2]	33.39[1]	33.72[1]	40.39[1]	40.43[1]	−6.94[4]	−6.68[4]
R^2		.366		.293		.386		.086
Mean	19.30		57.07		47.26		9.13	

NOTE: Table notes indicate significance of t ratios for coefficients (two-tailed test).
[1] > .01. [2] > .05. [3] > .10. [4] t ratio greater than 1.0.

TABLE 10-4
Effect of Specified Changes in Explanatory Variables as a Percentage of the Mean Consumption of Each Bundle Component by All Households

Variables	Dwelling Quality	Interior Space	Neighborhood Quality	Exterior Space
Race	−60.2	[1]	−12.6	−17.0
$5,000 income	15.0	9.3	3.2	73.8
4 years of education	26.5	3.5	5.0	17.0
10 years of employment	9.7	1.3	1.3	[1]
Head retired	36.7	[1]	5.2	19.4
Head unemployed	−12.4	–	−1.7	–
More than one employed	[1]	–	[1]	–
20 years of age	[1]	6.9	[1]	27.3
A family member	–	–	–	−2.7
An infant	–	1.4	–	–
A child	–	4.3	–	–
An adult	–	.3	–	–
Single female	7.7	−6.5	[1]	−29.5
Single male	−22.5	−7.8	−4.1	−45.3
Couple	10.6	−6.8	[1]	−48.4
Male head	[1]	[1]	[1]	[1]
Mean	19.30	57.07	47.26	9.13

[1]Coefficient less than one standard error.

they are discussed together. The effects of a five-thousand-dollar increase in income and four additional years of schooling on the consumption of each attribute bundle are summarized in Table 10-4. These effects are presented as a percentage of the mean consumption of each bundle by sample households. Four years of schooling correspond to the difference between an elementary-school and a high-school education, and between a high-school and a college education. Five-thousand dollars is slightly less than one sample standard deviation. In interpreting the estimates in Table 10-4, it should be remembered that a 1 percent increase in interior space or neighborhood quality is a much larger absolute increase in housing consumption than a 1 percent increase in exterior space or dwelling-unit quality.

It is apparent from Table 10-4 that a five-thousand-dollar increase in income has the largest percentage impact on the consumption of exterior space; it increases it by 74 percent from its average value. In contrast, four more years of education increase the consumption of exterior space by only 17 percent. The second largest percentage effects for both

income and education are obtained for dwelling-unit quality; a five-thousand-dollar increase in income increases the consumption of dwelling quality by 15 percent, and four additional years of schooling increase dwelling-quality expenditure by 26 percent.

Changes in income or education have only modest effects on the consumption of interior space; an extra five-thousand dollars in income increases the consumption of interior space by 9 percent, and four more years of schooling produce only a 4 percent increase. The effects of income and education on neighborhood quality are even smaller. Elasticities are another common measure of the effects of changes in income. The income elasticities, computed at the sample means, are .20 for dwelling quality, .12 for interior space, .04 for neighborhood characteristics, and .99 for exterior space.

Continuity of employment has its largest effect on the household's consumption of dwelling quality; continuous employment increases the household's consumption of dwelling quality 1 percent a year or 10 percent over ten years. For the remaining variables the effects of years of employment are quite small.

The retirement dummy, which presumably reflects a higher ratio of permanent to annual income for retired households as well as lags in adjustment, has a rather large effect on the consumption of all attribute bundles. Retired households consume 37 percent more dwelling quality, 5 percent more neighborhood quality, and 19 percent more exterior space than otherwise comparable households (Table 10-4). In the interior-space equation, the coefficient of the retirement dummy is smaller than its standard error.

Unemployment, which reduces the household's consumption of neighborhood quality and, particularly, dwelling quality, is not included in the space equations. The coefficient of age of the head of household is smaller than its standard error in the two quality equations but indicates that a household headed by a person fifty years old would spend 7 percent more for interior space and 27 percent more for exterior space than a household with otherwise similar characteristics headed by a person thirty years old.

The coefficients of the household-type and family-size and composition variables in the interior-space equations trace out an interesting pattern. The coefficients of all three dummy variables describing small households, i.e., single persons and couples, are approximately equal in magnitude and indicate that these small households consume between 6 and 8 percent less interior space than the average sample household. The consumption of interior space by families increases with family size, the magnitude of the increase depends on whether the additional family member are infants (age less than six), school children (age six to

eighteen), or adults (over eighteen). Additional school-age children have the largest effect on the consumption of interior space, while additional adults increase space consumption hardly at all.

None of the remaining equations include separate variables for the numbers of infants, children, and adults. The exterior-space equation, however, includes a single variable describing family size for households with children. It indicates that the consumption of exterior space declines by 3 percent with each additional family member. In addition, the dummy variables for household types indicate that single persons and couples consume between 30 and 48 percent less exterior space than the average household. These household-type variables are included in the two quality equations as well. They indicate that single males consume less of both neighborhood and dwelling-unit quality, particularly the latter, and that single females and couples consume more dwelling-unit quality than families of similar income, education, and labor-force attachment.

DEMAND FOR BUNDLE COMPONENTS BY BLACKS AND WHITES

Because of racial discrimination in urban housing markets, we expect both the quantities and composition of housing services consumed by black households to differ from those consumed by similar white households. The coefficients of the race dummy variables in Table 10-3 provide substantial evidence of such differences. We now further examine the effects of housing-market discrimination on black housing consumption by estimating separate relationships for black and white households.

As is true of most of the racially stratified equations presented in previous chapters, the black and white bundle-component equations in Table 10-5 appear quite similar overall. Certainly, the results provide little basis for the view that the unconstrained behavior of black housing consumers would differ substantially from that of whites of similar socioeconomic characteristics. Still, there are some important differences, which, we conclude, are best explained by the exclusion of black households from various parts of the housing market.

Except for the neighborhood-quality equation, the intercepts of the black bundle-component equations are smaller than those of the comparable white equations (Table 10-5). The difference is most pronounced for the exterior-space equation; the intercept of the black exterior-space equation is less than one-twentieth as large as the intercept of the

TABLE 10-5
Seemingly Unrelated Regression Estimates of Bundle Components for Black and White Households

	Dwelling Quality		Interior Space		Neighborhood Quality		Exterior Space	
Variables	Black	White	Black	White	Black	White	Black	White
Income	.52[3]	.57[1]	1.37[1]	1.01[1]	.25[2]	.29[1]	.16[2]	1.47[1]
Education	1.10[1]	1.36[1]	.43[3]	.53[1]	.36[1]	.70[1]	.08[4]	.60[4]
Years on current job	.16[2]	.20[1]	.06	.08[4]	.03	.07[1]	.00	−.06
Retired	7.37[1]	7.07[2]	−.43	1.70	2.64[2]	2.24[3]	−.38	2.04
None employed	−1.91	−3.00[4]	–	–	−1.18[4]	−.67	–	–
More than one employed	1.50	−1.51[4]	–	–	1.41[2]	−1.04[2]	–	–
Families								
Age	−.08[4]	.02	.29[1]	.16[1]	−.05[3]	.03[4]	.06[1]	.16[4]
Number of persons	–	–	–	–	–	–	.12[3]	−.31[4]
Number of infants	–	–	.73[4]	.88[4]	–	–	–	–
Number of children	–	–	2.97[1]	2.08[1]	–	–	–	–
Number of adults	–	–	−.27[4]	.28[1]	–	–	–	–
Male head	−1.60	−.72	1.10	−1.36	−.28	.54	.78[4]	−1.28[2]
Household types								
Single female	1.76	1.11	−2.56[4]	−4.46[1]	−.32	−.45	−.29	−4.78[4]
Single male	−4.69[3]	−4.14[2]	−7.90[1]	−2.71[4]	−1.50[4]	−2.23[2]	−.99[4]	−6.28[4]
Couple	2.57[4]	1.81[4]	−1.86	−4.89[1]	1.15[4]	−.44	−.78[4]	−5.77[3]
Constant	−2.25	2.35	28.27[1]	35.54[1]	39.22[2]	38.42[1]	.50	−10.36[4]

NOTE: Table notes indicate significance of t ratios for coefficients (two-tailed test).
[1]> .01. [3]> .10.
[2]> .05. [4] t ratio greater than 1.0.

comparable white equation. A small part of the lower consumption of dwelling-unit quality by blacks is traceable to the smaller intercept in the black equation. A more important explanation is the tendency, shown in Table 10-5, for blacks to spend a smaller fraction of each additional dollar of annual income on dwelling-unit quality, and to acquire less dwelling-unit quality for each additional year of schooling, than otherwise comparable white households. In the dwelling-unit-quality equations, whites buy 1.36 units more of dwelling quality for each additional year of schooling, whereas blacks buy only 1.10 units of dwelling quality for each additional year of schooling. Similarly, blacks consume .52 units of dwelling quality for each thousand-dollar increase in annual income as compared with .57 units of dwelling quality for whites.

It is hard to believe that these differences reflect differences in taste. Rather, we conclude that they result from the unfavorable terms at which dwelling-unit quality is available to black households. Moreover, a somewhat different picture emerges when these quantities are compared to the mean consumption of dwelling-unit quality. Because the mean consumption of dwelling-unit quality is much smaller for black than for white households, an equivalent increase in education or income leads to a much larger percentage increase in the consumption of dwelling-unit quality by black than by white households. For a five-thousand-dollar increase in income, black consumption of dwelling quality increases by 28 percent, as compared to an increase of only 12 percent for whites (Table 10-6). Similarly, the elasticity of income with respect to dwelling quality is .27 for blacks and .18 for whites. An additional four years of schooling increases black consumption of dwelling quality by 48 percent as compared to a 22 percent increase for whites. As before, both figures are computed at their means.

Black households increase their consumption of interior space by a larger amount with each thousand-dollar increase in income; the black coefficient of income in the interior-space equation is 1.37, whereas the white coefficient is only 1.01. A five-thousand-dollar increase in income increases black consumption of interior space by 12 percent and white consumption of interior space by 8 percent. The corresponding elasticities are .12 for the black equation and .13 for the white equation. The education coefficient is larger in the white interior-space equation than in the black interior-space equation. The consumption of interior space increases more rapidly with age for blacks than for whites.

The findings for the exterior-space equation reflect the limitations on black occupancy of single-family units and the exclusion of black households from the newer suburbs. For whites, the elasticity of income with respect to the consumption of exterior space is quite large, 1.02. By

TABLE 10-6
Effect of Specified Changes in Explanatory Variables as a Percentage of the Mean Consumption of Each Bundle Component by Blacks and Whites

	Dwelling Quality		Interior Space		Neighborhood Quality		Exterior Space	
Variables	Black	White	Black	White	Black	White	Black	White
$5,000 income	28.4	11.7	12.4	8.7	2.9	2.9	14.3	66.6
4 years of education	48.4	22.2	3.1	3.6	3.4	5.6	6.2	21.7
10 years of employment	18.0	8.0	[1]	1.3	[1]	1.5	[1]	−5.9
Head retired	81.0	28.8	[1]	[1]	6.2	4.5	[1]	[1]
Head unemployed	[1]	−12.2	–	–	−2.8	−1.4	–	–
More than one employed	[1]	−6.2	–	–	3.3	−2.1	–	–
20 years of age	−18.7	[1]	10.6	5.5	−2.3	1.3	23.4	28.2
A family member	–	–	–	–	–	–	2.3	−2.8
An infant	–	–	1.3	1.5	–	–	–	–
A child	–	–	5.4	3.6	–	–	–	–
An adult	–	–	−.5	.5	–	–	–	–
Single female	[1]	[1]	−4.6	−7.7	[1]	[1]	[1]	−43.3
Single male	−51.5	−16.9	−14.4	−4.7	−3.6	−4.5	−18.3	−56.9
Couple	28.2	7.4	[1]	−8.4	2.7	[1]	−14.3	−52.3
Male head	[1]	[1]	[1]	[1]	[1]	[1]	14.4	[1]
Mean	9.10	24.52	55.03	58.11	42.21	49.84	5.42	11.03

[1]Coefficient less than one standard error.

comparison, for blacks this elasticity is only .12, which is hardly surprising in light of the previous analysis of the lower home-purchase probabilities for blacks.

Years of continuous employment behaves in a manner similar to income and education in the bundle-component equations. It is positive in all but one case, consumption of exterior space for whites. The coefficients of the white equation are larger than the comparable ones in the black equations for all but the exterior-space equations.

The retirement dummy is positive in all but two equations, the interior- and exterior-space equations for blacks. Its effects are particularly pronounced in the dwelling-unit-quality equations, particularly the equation for blacks. Retirement increases the consumption of dwelling quality of black households by 81 percent, as contrasted with an increase of 29 percent for whites (Table 10-6). The age variable also behaves like an income or wealth variable in all but the black dwelling-unit-quality and neighborhood-quality equations.

The household size and composition variables are generally consistent between pairs of black and white equations. In the dwelling-unit-quality equations, all of the household-type variables have the same signs, and the magnitudes are not widely different. The difference in dwelling-unit-quality consumption between single black females and single black males living alone is greater than the difference between these same types of white households. Black couples consume more dwelling-unit quality relative to families than do white couples.

Differences between blacks and whites in the interior-space equations are somewhat larger than in the dwelling-quality equations. With two exceptions, however—the dummy variable for male-headed families and the variable for number of adults—the signs of the coefficients of the family-size and composition variables are the same.

The largest differences in the magnitudes of the household-type variables are obtained for the exterior-space equations. In both the black and white equations, single persons and couples consume considerably less exterior space than do families with children. These differences are far more pronounced for whites than for blacks. The variable reflecting number of persons behaves differently for blacks than for whites; an increase in the number of persons for families with children increases the consumption of exterior space by black households, while it decreases consumption for whites.

The white attribute-bundle equations in Table 10-5 can be used to estimate black housing consumption in the absence of housing-market discrimination. These estimates, summarized in Table 10-7, indicate that actual black consumption of dwelling-unit quality is less than half as large as it would be in the absence of housing-market discrimination. By

TABLE 10-7
Actual Mean Black and White Consumption of Bundle Components and Estimated Black Consumption Using Black Means in White Equations

Bundle Components	Actual Black	Estimated Black	Actual White
Dwelling quality	9.10	20.53	24.52
Interior space	55.03	55.07	58.11
Neighborhood quality	42.21	48.08	49.84
Exterior space	5.42	6.21	11.03

comparison—using the rental price weights, at least—racial discrimination does not seem to reduce the consumption of interior space by black households.[3] The results also suggest that the consumption of neighborhood quality by black households is more than 12 percent less than for whites; the consumption of exterior space by blacks is approximately the same.

In summary, the estimates in Table 10-7 suggest that socioeconomic differences between black and white households (that is, differences in income, family size and composition, and labor-market attachments) account for the bulk of the differences in interior-space consumption, and for much of the difference in exterior-space consumption between races. For both dwelling-unit and neighborhood quality, however, the large differences between black and white consumption are best explained by systematic differences in access to the housing stock due to racial discrimination.

USE OF VALUE WEIGHTS TO DEFINE BUNDLE COMPONENTS

In our discussion of the attribute prices used to define bundle components, we argue that a properly specified index of imputed rental prices would be more suitable than imputed market values. Nonetheless, we now present a separate analysis of the demand for bundle components by the owner-occupants of single detached units, based on the

[3]If floor area were included as a measure of interior space, this relationship might be modified somewhat since single-family detached areas typically have more usable floor area per dwelling unit than multifamily units.

coefficients of nonghetto owner-occupied value equations. This analysis permits us to evaluate directly the effect of alternative weighting schemes.

Because the explanatory variables included in the rent and value equations are slightly different, more than a simple index-number problem is involved. Virtually all single-family detached units possess hot water and central heating. As a result, these attributes are not included in the value equations. As long as the analysis is limited to the single-family sample, no difficulties arise. However, we encounter problems as soon as we use these price weights to describe either the entire sample or the sample of rental units, in which the presence or absence of central heating appears to be an important element of—or a good proxy for—dwelling quality. At the same time, the single-family owner-occupied equations include a floor-area variable. As the discussion in Chapter 8 has indicated, floor area varies considerably within size classifications measured by the number of rooms; thus, use of the first-floor area considerably increases the precision of our measurement of dwelling-unit size. Unfortunately, floor-area measurements are unavailable for multifamily units in the sample.

Except for these differences, variables in the nonghetto value equation used to estimate the price coefficients for the bundle components are identical to those presented previously. Equations 10-9 to 10-13 define these quantities (or implicit expenditures). Again, t ratios are presented in parentheses.

(10-9) Dwelling quality (DQ) = 1467 Interior condition − 268 Exterior condition − 53.11 Age of structure
(2.512) (−0.326) (−3.244)

(10-10) Interior space (IS) = 4821 Logarithm of number of rooms + 10.56 First-floor area (000 square feet) + 1345 Number of baths
(3.965) (12.58) (2.223)

(10-11) Neighborhood quality (NQ) = 128 Quality of adjacent units + 805 Block-face quality − 208 Median schooling
(0.221) (1.464) (−0.978)

(10-12) Exterior space (ES) = .7394 Parcel area (000 of square feet)
(0.624)

(10-13) Constant = −9542
(−2.339)

An indication of the effect of using these different weights in defining bundle components is provided by the data in Table 10-8. Shown in Table 10-8 are mean values of the bundle components using nonghetto renter weights for all households, for renters, and for owners; also shown are means for single detached owner-occupied units, using nonghetto value weights. The sum of the bundle components for owner-occupants, using the renter weights, is of course an estimate of what the monthly rent of these properties would be in the nonghetto rental market, assuming no utilities or furnishings were provided. Similarly, the sum of the attribute bundles computed from the value weights provides an estimate of the mean selling price of these properties in the nonghetto owner market. The estimated rental value is $106.57, whereas the estimated sales price of these same properties outside the ghetto is $16,618. This latter figure is surprisingly close to the mean value of these properties, $16,512.

The estimated rental value of single detached owner-occupied units and the estimated mean market value can, of course, be used to compute a value/rent ratio. This ratio is similar to the gross rent multipliers discussed previously. The calculations in Chapter 7, however, used gross rents, i.e., including the normal proportion of utilities, as the denominator of the value/rent ratio, whereas this computation uses net rents, i.e., all imputed payments for utilities or furnishings are subtracted. Using these assumptions, a value/rent ratio can be used to convert bundle components based on value weights to rental equivalents. This procedure, shown in the third column of Table 10-8, facilitates our evaluation of the effects of weighting.

The value equation also has a large negative intercept. In fact, when it is converted to monthly equivalents, it is larger in absolute value than the intercept of the rental equation. In Table 10-9, we present estimates of bundle components for all households, renters, and owners after the constant term has been allocated to the four bundles in proportion to the means of each subgroup. For owners, the bundle components are shown computed from both owner and renter weights.

The last four columns in Table 10-9 are the most pertinent to a discussion of the effects of the different price weights. The third and fourth columns present alternative estimates of the amount of housing output accounted for by each of the four bundle components, applying first the rental weights—Equations 10-1 to 10-5—and then the value weights—Equations 10-9 to 10-12—to the same sample of owner-occupied single detached units. It is apparent from a comparison of these two columns that the two weighting schemes produce substantially different results. Since the sums of the two columns are the same, 106.57, it is

TABLE 10-8
Means and Standard Deviations of Bundle Components of Owner-Occupied Single Detached Units, Based on Value Weights; Compared with Mean Quantities, Based on Implicit Gross Rent Multiplier; and Mean Quantities for All Units, Rental Units, and Owners, Based on Rental Weights

	Owner Weights Single Detached Housing			Renter Weights		
	Mean	Standard Deviation	Rental Equivalents (÷155.94)	All Units	Rental Units	Single Detached Housing
Bundle components						
Dwelling quality	3,562	1,811	22.84	19.30	4.12	28.67
Interior space	21,264	5,643	136.36	57.07	50.25	65.40
Neighborhood quality	1,272	662	8.16	47.26	44.93	51.64
Exterior space	62	149	.40	9.13	4.34	17.88
Constant	−9,542		−61.19	−24.62	−24.62	−24.62
Rent corrections				−32.40	−32.40	−32.40
Constant plus rent corrections				−57.02	−57.02	−57.02
Net rent (value)	$16,618		$106.57		$46.62	$106.57

TABLE 10-9
Quantities of Bundle Components for All Housing Units, Rental Units, and Single Detached Owner-Occupied Units After Allocation of Constant Terms

	All Units	Rental Units	Single Detached Owner-Occupied Units			
					Percent of Total Services	
	Renter Weights	Renter Weights	Renter Weights	Owner Weights	Renter Weights	Owner Weights
Bundle components						
Dwelling quality	11.01	1.85	18.68	14.51	17.5	13.6
Interior space	32.56	22.60	42.60	86.62	40.0	81.3
Neighborhood quality	26.96	20.21	33.64	5.18	31.6	4.9
Exterior space	5.21	1.95	11.65	.25	10.9	.2
Total services	75.74	46.62	106.57	106.57	100.0	100.0

convenient to examine the two sets of quantities as percentages of total housing output. The last two columns provide these comparisons.

Use of renter weights allocates a much larger part of total housing output of the sample of owner-occupied detached units to neighborhood quality and exterior space, somewhat more to dwelling-unit quality, and a much smaller proportion to interior space than if value weights are used. If the value weights are used, fully 81 percent of housing output is allocated to the interior-space component, a proportion twice as large as that obtained with renter weights.

Several reasons for these differences may be offered. First, as noted earlier, the use of weights derived from the housing value equations includes expectations about capital gains and losses, as well as quantities of current services. If the expected capital gains associated with neighborhood characteristics are lower than those associated with dwelling-unit characteristics, the price weights derived from the value equations may give less importance to neighborhood quality than the true value of their current services. Since most of the single detached units in this sample are located in the central city, expectations about continuing neighborhood decline may be an important explanation of the difference in the allocation of housing output when rental and value weights are used.

In addition, the rental equations lack a measurement of floor space, whereas the value equations include first-floor area as a proxy. As the equations in Chapter 8 make clear, floor area is an important independent determinant of the value of single-family homes; and substantial variations in size, as measured by floor area, exist within room size categories. The rental equations may simply fail to measure interior space adequately.

Finally, the relatively high correlation between interior space and the other three bundle components may explain the difference in the allocation of housing output. This association, which is present for rental units, may be much more important for single-family units. Neighborhoods where owner-occupied single-family homes are concentrated are probably more homogeneous than multifamily-dwelling neighborhoods. Such homogeneity produces both statistical and theoretical difficulties. A statistical consequence could be that the estimates obtained for neighborhood and dwelling-unit quality and exterior space are biased toward zero.

The value equation used provides some evidence in support of this proposition. The coefficient of the exterior condition variable has the wrong sign, with a t ratio of only .3. The coefficient of median schooling is about equal to its standard error. The parcel-area variable is, of course, more homogeneous in the single-family equation than in the

rental equation, but it also has a much smaller variance and is highly correlated with both number of rooms and size.

DEMAND FOR BUNDLE COMPONENTS BY OWNER-OCCUPANTS

The component demand functions, shown in Table 10-10, resemble the pooled estimates shown in Table 10-3 even more than might have been expected. (As we have noted, using owner rather than renter weights alters the composition of housing output of the owner-occupied

TABLE 10-10
Seemingly Unrelated Regression Estimates of Bundle Components for Owner-Occupied Single Detached Units with Deflated Owner Weights[5]

Variables	Dwelling Quality	Interior Space	Neighborhood Quality	Exterior Space
Race	−12.56[1]	−7.64[2]	−4.80[1]	−.15[4]
Income	.16[3]	3.06[1]	.04[4]	.04[1]
Education	.84[1]	1.81[1]	.24[1]	.02[4]
Years on current job	.11[2]	−.04	.01	−.01[4]
Retired	12.72[2]	−1.98	1.80	−.11
None employed	−9.75[2]	–	−1.64	–
More than one employed	1.28[4]	–	.77[3]	–
Families				
Age	−.09[3]	.44[2]	.01	.00
Number of persons	–	–	–	−.01[4]
Number of infants	–	3.01[3]	–	–
Number of children	–	3.27[1]	–	–
Number of adults	–	.27	–	–
Male head	1.62	5.13	1.46[4]	−.08
Household types				
Single female	−1.10	4.90	−.74[4]	.00
Single male	−3.04[4]	6.09	−.30	−.14
Couple	1.50[4]	.28	.78[4]	−.07
Constant	17.38[1]	63.73[1]	5.02[1]	−.14

NOTE: Table notes *1* through *4* indicate significance of *t* ratios for cofficients (two-tailed test).

[1] > .01.

[2] > .05.

[3] > .10.

[4] *t* ratio greater than 1.0.

[5] Original coefficients divided by 155.94.

sample.) Still, there are some important differences. For example, the pooled equation based on renter weights revealed no tendency for black households to consume less interior space than similar white households. From Table 10-10, however, it is apparent that when owner weights are used to define output, black owner-occupants consume less interior space than white owner-occupants of similar incomes, labor-force attachment, and family size and composition. From Table 10-11, it can be seen that this difference amounts to about 6 percent of the average consumption of interior space by owner-occupants of single detached units. The significance of this estimate becomes obvious when it is recalled that with the value weights, interior space accounts for 81 percent of total housing output of single detached units.

From Table 10-11 it is apparent that blacks consume far less of the remaining bundle components as well. The difference in dwelling quality, −55 percent of the mean consumption of dwelling quality by the owner-occupants of single detached houses, is roughly comparable to

TABLE 10-11
Effect of Specified Changes in Explanatory Variables as a Percentage of the Mean Consumption of Each Bundle Component by Owners of Single Detached Units

Variables	Dwelling Quality	Interior Space	Neighborhood Quality	Exterior Space
Race	−55.0	−5.6	−58.8	−38.5
$5,000 of income	3.6	11.2	2.6	50.9
4 years of education	14.8	5.3	11.6	18.7
10 years of employment	4.9	[1]	[1]	−20.5
Head retired	55.7	[1]	[1]	[1]
Head unemployed	−42.7	–	[1]	–
More than one employed	5.6	–	9.4	–
20 years of age	−8.1	6.5	[1]	[1]
A family member	–	–	–	−3.8
An infant	–	2.2	–	–
A child	–	2.4	–	–
An adult	–	[1]	–	–
Single female	[1]	[1]	−9.0	[1]
Single male	−13.3	[1]	[1]	[1]
Couple	6.6	[1]	9.6	[1]
Male head	[1]	[1]	17.9	[1]
Mean	24.5	146.2	8.7	.43

[1]Coefficient less than one standard error.

the figure obtained using the rental weights for the entire survey. The neighborhood quality figure, −59 percent, is, however, much larger.

Even so, the general pattern of results shown in Table 10-11 is quite similar to the findings obtained for the entire sample, using the renter weights. The consumption of all four bundle components increases with income and years of education of the head. Increases in income have a relatively larger effect on the consumption of interior and exterior space, while additional years of education have relatively larger effects on dwelling-unit quality and exterior space. An additional five-thousand dollars in income increases the consumption of dwelling quality by 4 percent, of interior space by 11 percent, of neighborhood quality by 3 percent, and of exterior space by 51 percent, relative to the means of the respective quantities. The effects of additional years of schooling are more uniform. An additional four years of schooling increases the mean consumption of dwelling-unit quality by 15 percent, of interior space by 5 percent, of neighborhood quality by 12 percent, and of exterior space by 19 percent.

Of the remaining variables whose coefficients exceed one standard error, retired households spend a great deal more on dwelling-unit quality—56 percent of the mean consumption—than their income, education, and family circumstances would indicate; households with unemployed heads consume much less dwelling-unit quality than households with employed heads. In the interior-space equation, an additional infant and an additional child increase space consumption by roughly the same amount, a modest 2 percent.

SUMMARY

This chapter utilizes the information on the market prices of housing attributes, analyzed in Chapter 8, to depict households' demand for several conceptually distinct components of the housing bundle. Previous analyses by other researchers, and our own analysis in Chapter 7, have studied housing demand measured in terms of total payments for housing services.

In contrast, our analysis in Chapter 9 investigates the demand for some 21 physical components of housing services. Chapter 10 aggregates these physical components into four composites by using the implicit prices of the attributes as a numeraire. The analysis can be interpreted as an extension of previous demand studies by providing an analysis of households' implicit payments for several distinct components of housing services.

We define four components of housing services: dwelling quality,

interior space, neighborhood quality, and exterior space. We then investigate household demand for these components (aggregated in two ways, by the prices estimated in the rental market and in the market for owner-occupied housing) in a manner which incorporates the budget constraints of households.

The results suggest a consistent pattern of substitution among these components by housing consumers. Increases in income and education are associated with substantially greater consumption of exterior space (i.e., parcel area) and dwelling quality (i.e., the interior and exterior quality of units, the presence of hot water and central heating, and the newness of the structure). Increases in family size are associated with greater consumption of interior space. Again, the presence of younger children induces greater increase in demand for interior space than do either infants or adults.

When the implicit prices of rental or owner-occupied units are used to define the four composite bundles of housing services, the results indicate that there are substantial differences in consumption between otherwise comparable white and black households. These differences are highlighted by the separate analysis of black and white households, using the rental-market weights to define the composite bundles. The results suggest that black households consume substantially less dwelling quality, neighborhood quality, and exterior space than white households of identical size, composition, and labor-market attachment.

When viewed in the context of the preceding chapters, these results provide further evidence of the way in which limitations on residential choice affect black households as housing consumers. Previous analysis suggests that housing prices are higher in the ghetto than in the nonghetto portion of the housing stock and that, as a result, black households spend less on housing than comparable white households. The results of this chapter indicate that black households do not spend less on some aspects of housing, namely the size of dwelling units, but they do consume substantially less exterior space and lower levels of neighborhood and residential quality. These are, of course, the attributes of housing services that are in short supply in the black ghetto and are those which are less elastically supplied as the ghetto housing stock increases by peripheral expansion.