INCOME ELASTICITY OF HOUSING DEMAND

JOHN MULFORD

R-2449-HUD

JULY 1979

HOUSING ASSISTANCE SUPPLY EXPERIMENT

Sponsored by

The Office of Policy Development and Research
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PREFACE

This report was prepared for a conference on the housing choices of low-income families sponsored by the Office of Policy Development and Research, U.S. Department of Housing and Urban Development (HUD).

The report draws on research conducted by Rand as part of the HUD-sponsored Housing Assistance Supply Experiment (HASE). The author wishes to thank C. Lance Barnett, Ira S. Lowry, Daniel A. Relles, and C. Peter Rydell for helpful suggestions during the research and for reviewing an early draft of this report. Emmett Keeler and Charles Phelps provided detailed comments that are reflected in the final version. Judy Bartulski typed the various drafts; Jean Houston was the production typist. Jeanne Dunn edited the report and supervised its production.

SUMMARY

This report estimates the longrun income elasticity of housing expenditures (η) for owners and renters using cross-sectional data from the two Housing Assistance Supply Experiment (HASE) sites--Brown County, Wisconsin, and St. Joseph County, Indiana. Intersite differences are not statistically significant, so results are averaged across sites. Differences by tenure are significant, so both the owner estimate (0.45) and renter estimate (0.19) are reported. An assessment of possible biases in each estimate suggests that the tenure difference is probably slightly overstated.

Income elasticities estimated with "permanent income"--here measured by three-year average annual income--should contain less bias than those estimated with current (annual) income. Because HASE surveys track a panel of properties, not households, permanent income can be measured only for the sample of households that remained in their housing units for three surveys. Potential biases on η caused by sample attrition are assessed and judged small.

Results from a constant elasticity model are compared with those from models which allow η to vary with income--linear, spline, and log-exponential models. The evidence is consistent with either constant or slightly increasing elasticity with income.

An interest in low-income households implies an interest in those headed by elderly persons, or single parents, and those composed of young couples with young children. Although sample sizes are not large enough for conclusive statistical inferences, some samples indicate that elderly and single-parent households spend more on housing than others, but increase their expenditures at a lower rate as incomes rise (i.e., have a lower income elasticity).

The most important conclusion of this study is that the income elasticity of housing expenditures in the HASE sites is very low, both absolutely and relative to conventional wisdom and recently published estimates. If these findings are generally correct, pure income transfers will not much affect recipients' housing expenditures.

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I. INTRODUCTION

The ability of housing assistance programs to increase housing consumption by participants depends critically on the relationship between household incomes and housing expenditures. The income elasticity of housing expenditures (η) succinctly summarizes that relationship.*

The income elasticity, η, is defined as the first derivative of housing expenditures with respect to income times the ratio of income to housing expenditures. For small changes, η is the ratio of percentage change in housing expenditures to percentage change in income. For example, $\eta = 0.5$ means that a 2 percent increase in income will cause a 1 percent increase in housing expenditures.

The housing literature contains many estimates of η, but they vary so much that at the extremes they suggest different policies. The lowest estimates ($\eta \cong 0.1$) imply that housing expenditures hardly respond to increases in income; therefore, only strong earmarking will ensure that a substantial fraction of cash transfers are spent on housing. The highest recent estimates ($\eta \cong 1.0$) imply that housing expenditures increase at the same rate as income; therefore, a substantial fraction of cash transfers would be spent on housing without earmarking.

The wide range of elasticity estimates raises at least two questions: Why do the estimates vary so much? Which, if any, is correct? Table 1 organizes recent estimates by three dimensions that explain much of the variation: income measure, tenure, and type of data.

Proponents of the permanent income hypothesis** have argued persuasively that households consider more than one year's income when they make housing choices. Current (annual) income measures permanent income with error, because of year-to-year fluctuations in the former.

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*If prices are constant across observations and households are consuming their equilibrium quantity of housing, η is also the income elasticity of housing demand--i.e., the terms housing expenditures and quantity of housing demanded are equivalent except for a scale factor.

**See Friedman, 1957, for the permanent income hypothesis and application to consumption expenditures in general.

Table 1

ESTIMATES OF THE INCOME ELASTICITY OF HOUSING EXPENDITURES
FROM SELECTED STUDIES

Type of Data and Author	Sample Coverage		Estimated Income Elasticity			
			Owners		Renters	
	Location	Period	Current Income	Permanent Income	Current Income	Permanent Income
Aggregate (multicity)						
de Leuuw	U.S.	1960	--	1.34	--	.81
Household (multicity)						
Lee	U.S.	1959-61	.38	.70	.33	.42
Carliner	U.S.	1968-71	.50	.75	.44	.52
Stegman and Sumka	N. Carolina	1970	--	--	.25	.40
Household (single city)						
Low to middle incomes:						
Kain and Quigley	St. Louis	1967-68	.13	--	.08	--
Friedman and Weinberg	Phoenix,	1973-76	--	--	--	.36
	Pittsburgh		--	--	--	.36
All incomes:						
Mulford	Brown Co.,	1974-77	.38	.51	.12	.22
	St. Joseph Co.		.28	.40	.11	.15

SOURCES: de Leeuw, 1971, pp. 8-9; Lee, 1968, pp. 485-486; Carliner, 1973 p. 530; Stegman and Sumka, 1978, p. 54; Kain and Quigley, 1975, p. 159; Friedman and Weinberg, 1978, p. 7; Mulford, this report.

Error in an independent variable of a regression biases its coefficient downward;* therefore, current income elasticities underestimate the permanent income elasticity. In Table 1, current income elasticity estimates are lower than permanent income estimates for every study that reports both.

Income elasticities also vary by tenure. Owners seem to have a greater demand for housing than renters, even after controlling for plausible determinants of taste, such as household size and composition. Owner elasticity estimates are greater than renter estimates for every study that reports both.

Controlling for income measure and tenure does not erase all the differences in Table 1. Each column contains substantial variation, much of which relates to the type of data used in the study. Studies that aggregate household data, usually by geographic area, produce higher elasticity estimates than those that use individual household data as observations. Aggregation algorithms that group households with similar values of the dependent variable, housing expenditures, cause upward bias in the income elasticity estimates.**

Finally, the data base may consist of observations from a single city or from many cities. Since the price of housing varies more across cities than within them and housing prices are notoriously difficult to measure accurately, multicity estimates are more likely to suffer biases from unmeasured price variation than single city estimates. If the price of housing is omitted or measured with error and it is positively correlated with income (as it is likely to be across cities), income elasticity estimates will be biased upward.***

The discussion above suggests that a sample of individual household data from a single city using permanent income should produce less biased estimates of the income elasticity than alternative data

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*See any basic econometrics text such as Johnston, 1972, p. 281.

**For example, Lee, 1968, pp. 487-488, argues that grouping by census tract leads to upward bias.

***See Polinsky, 1977, for a discussion of biases with various data bases and hypothesized correlations between housing price and income.

bases. However, even with such a sample, large owner-renter differences occur and seem unshakable and valid; therefore, we should abandon the idea of a single income elasticity for all households at all times. Income elasticities might also vary along dimensions not represented in Table 1. This study found instances of variation by household type and income level, although the findings were not consistent across samples.

All of the studies in Table 1 use cross-sectional data, and thus estimate the longrun income elasticity. Because households do not adjust their housing consumption instantaneously when their incomes change, the shortrun elasticity will be lower than the longrun elasticity, approaching it as an upper bound over time. By indicating where the population is headed, the cross-sectional elasticity might serve as a useful benchmark for further research on the dynamics of housing consumption adjustment. But judging from the elasticity estimates of this report--0.19 for renters and 0.45 for owners--the longrun adjustment is so small that it makes the time path of adjustment uninteresting.*

The implications of those estimates for the housing effects of unrestricted income transfers are striking. A cash grant that equals 25 percent of pregrant income would elicit at most (in the long run) a 5 to 11 percent increase in housing expenditures, which would result in only 10 to 22 percent of the grant going to increased housing expenditures for a household with a pregrant expenditure-to-income ratio of 0.5.**

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*Although total expenditures change by a small amount, the nature of the change--e.g., along dimensions of space, locational services, structural quality, and price--may vary in important ways across household types.

**The smaller numbers refer to renters, the larger to owners. Using renters as an example, a 25 percent increase in income (Y) causes about a 5 percent increase in housing expenditures (E) when $\eta = 0.2$. The fraction of the grant (G) going to increased E is $\Delta E/G$:

$$\frac{\Delta E}{G} = \frac{\Delta E}{\Delta Y} = \eta\frac{E}{Y} = (0.2)(0.5) = 0.10 \text{ from } \eta = \frac{\Delta E}{\Delta Y}\frac{Y}{E}, \text{ where } \Delta$$

means change and $\Delta Y = G$.

The small housing expenditure effect does not imply that low income households are behaving perversely, nor does it imply that strong earmarking would be a good idea. Rather it is consistent with the hypothesis (and observation in HASE data) that most low income households secure adequate or nearly adequate (i.e., inexpensive to repair) housing by spending large fractions of their incomes on housing. Such households use increases in income to reduce housing expenditure burdens rather than to increase housing consumption.

This report is based on data from the Housing Assistance Supply Experiment (HASE). HASE is part of the experimental housing allowance program begun in 1972 by the Office of Policy Development and Research, U.S. Department of Housing and Urban Development (HUD). The experiment entails operating a fullscale allowance program in two sites (Brown County, Wisconsin, whose main city is Green Bay, and St. Joseph County, Indiana, whose main city is South Bend), and monitoring market responses and program operations for about five years.

Using cross-sectional data from the two HASE sites, this report estimates the longrun income elasticity of housing expenditures for owners and renters in each site. Section II describes the HASE data base, sampling procedures, and measures of income and housing expenditures. Section III presents a constant elasticity model of housing expenditures and discusses its estimation with current and permanent income. Section IV searches for variation in η with income, and Sec. V summarizes the results and suggests directions for further research. Appendix A presents means and standard deviations of variables used in the analysis. Appendixes B and C present detailed results of models with interaction terms and models with variable income elasticity, respectively.

II. THE DATA BASE

SAMPLING

To monitor the housing market's response to a housing allowance program, HASE conducted four annual cycles of field surveys addressed to owners and occupants of a marketwide sample of residential properties. The sample design provided for probability sampling in each of 18 strata of residential properties distinguished by location (urban versus rural), tenure (rental versus ownership), size (number of housing units), and cost (gross rent or estimated market value).

Each year, attempts to interview the occupants of more than 3,000 housing units resulted in completed questionnaires for more than 2,000 in each site. The questionnaire explores several topics including housing expenses, household composition, income, education, occupation, employment history, and residential mobility history. Within the limits of sampling reliability and possible nonresponse bias, the data can support generalizations about the population of 43,830 households in Brown County and 74,336 households in St. Joseph County.*

Using housing expenditure and household characteristic data from the baseline surveys and household income data from the first three waves of surveys, we constructed two analysis samples: the current income sample and the permanent income sample, where current income is annual income and permanent income is three-year average annual income. The current income sample consists of households who completed baseline interviews and, if renters, paid full market rent. The permanent income sample consists of households in the current income sample who remained in the same unit for the second and third survey waves and completed interviews for both.

The peculiar composition of the permanent income sample--nonmovers for more than two years--derives from the HASE design. To detect

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*Population totals were estimated from baseline survey data from 1974 in Brown County and from 1975 in St. Joseph County. Resident landlords in both sites and residents of subsidized housing in Brown County were excluded from the sample and hence from the population estimates.

marketwide price inflation caused by the housing allowance program, HASE surveys track a panel of properties rather than households. Since households that move also leave the panel of properties,* we can compute three-year average annual income only for households that stayed in the same unit for three surveys.

Considerable sample shrinkage occurred between the current and permanent income samples, as Table 2 shows. Shrinkage for renters exceeded that for owners (82 percent versus 57 percent), reflecting the higher moveout rate of the former. Despite shrinkage, all samples (both sites, both tenures) provide coverage of the entire income spectrum, allowing comparisons and contrasts of households by income. In particular, the data can support a test of whether the income elasticity varies with income level.

The relative frequencies of owners and renters in the current income sample reflect the HASE design, but not the population. Renters were sampled at a higher rate than owners because their greater heterogeneity required more extensive stratification, and because most pre-experimental concern about potential allowance-induced housing price inflation focused on renters. Owners represent 74 percent of all households in the population and 64 percent of low-income households, as Table 3 shows. A comprehensive study of low-income households in the HASE sites must include both owners and renters.**

Besides high ownership rates, Table 3 also shows that 85 percent of low-income households belong to one of four household types: young couples with young children, single parents, elderly singles, and elderly couples. Only one of those types--young couples with young children--accounts for a similar share of the general population. A

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*Only a handful of households moved from one sampled unit to another and completed three annual surveys.

**Ownership rates in the HASE sites somewhat exceed national averages. According to the U.S. Bureau of the Census, 1976, Tables A.1 and A.2, 64.6 percent of all occupied housing units and 47.7 percent of those occupied by households with annual incomes below $5,000 were owner occupied. These national percentages also indicate the inclusion of both owners and renters in a study of the low-income population.

Table 2

INCOME DISTRIBUTION OF ANALYSIS SAMPLES, WITH SAMPLE SIZES

Income ($)[a]	Percentage Distribution			
	Current Income Sample		Permanent Income Sample	
	Owners[b]	Renters	Owners[b]	Renters
Brown County				
0-5,999	10	38	8	30
6,000-11,999	34	41	22	41
12,000 or more	56	21	70	29
Total	100	100	100	100
Sample size	535	1,906	220	404
St. Joseph County				
0-5,999	36	71	15	43
6,000-11,999	32	22	32	34
12,000 or more	32	7	53	23
Total	100	100	100	100
Sample size	401	1,364	179	196

SOURCE: Tabulated by HASE staff from records of the household surveys, baseline through wave 3, Brown and St. Joseph counties.

[a]For the current income sample, entries are based on income for the year preceding the baseline survey. For the permanent income sample, entries are based on three-year averages of annually reported incomes.

[b]Single-family houses only; condominiums, cooperatives, and mobile homes excluded.

study of the behavior of low-income households should test for differences between those groups.

MEASUREMENT

The variables in this analysis are household income; housing expenditures; household size, type, and race; and location of residence. All variables except income refer to the baseline survey year--1974 in Brown County and 1975 in St. Joseph County. Income data refer to the

Table 3

DISTRIBUTION OF HOUSEHOLDS AND OWNERSHIP RATES BY HOUSEHOLD TYPE

Household Type	Percentage Distribution		Percent Homeowners	
	Low-Income Households[a]	All Households	Low-Income Households[a]	All Households
Nonelderly:				
Young couple, young children	16	23	54	79
Single parent	19	6	39	45
Other nonelderly[b]	15	53	61	73
Elderly:				
Single	31	9	73	74
Couple	19	9	88	90
All types	100	100	64	74

SOURCE: Tabulated by HASE staff from records of the baseline household surveys, Brown and St. Joseph counties.

[a]All households that were estimated to be eligible for the housing allowance program at baseline. Eligibility is based on assets and family composition in addition to income. Nonelderly single persons living alone were not eligible, so are excluded.

[b]Includes nonelderly singles, nonelderly couples, young couples (head under 46) with older children, and middle-aged couples (head 46-61) with children.

calendar year preceding the survey year. Current income refers to the year before baseline. Permanent income, which is the simple average of three years of annual income, brackets baseline by referring to the years preceding, coinciding with, and succeeding the baseline year in each site.

Annual household income is adjusted gross income, where gross income is the sum of reported income from all sources, including wages and salaries, interest and dividends, pensions, social security, several categories of public assistance, alimony and child support, and business and property income. The adjustment adds the cash value of food stamps and subtracts alimony and child support payments made by the household as well as child-care expenditures necessitated by employment. For owners, 8 percent of equity in the home is imputed as income.

Housing expenditures, the dependent variable in this analysis, are measured by gross rent for renters and equivalent gross rent for owner occupants. Gross rent equals contract rent plus tenant-paid utilities--i.e., it includes all payments for the flow of residential services from a unit.

For owners, a measure comparable to gross rent is the amount their unit would rent for--i.e., its equivalent gross rent. By approaching the quantity of housing services of owner-occupied units indirectly, through equivalent gross rent, we avoid the problem of measuring homeowner payments for housing services which include an uncertain capital gains component (as a negative payment).

Appealing to market efficiency, we assume that the ratio of rent to capital value is the same for all single-family houses.* Therefore,

---

*Capital values and rents should be equal for equivalent owner-occupied and rented single-family houses because conversions are as simple as putting out a "for rent" sign or a "for sale" sign. However, if landlords are able to predict the moveout rate of potential tenants and charge high turnover households more because they impose greater vacancy losses, then gross rent divided by capital value for rented houses should be greater than equivalent gross rent divided by capital value for owner-occupied houses, because owners have lower moveout rates. The hypothesis of charging for expected moveout rate--as opposed to rewarding length of stay with a rent discount--is as yet untested. If landlords can charge for expected moveout rate, the equivalent gross rents in this report are too large.

the equivalent gross rent of an owner occupied house equals its capital value times the ratio of gross rent to capital value for similar rented houses.

Table 4 presents such ratios for each of three areas with different market conditions and for three intervals of housing unit age. The entry in each cell was computed by averaging the gross rent/capital value ratios for rented houses in that cell and smoothing (see note to Table 4). The multipliers are highest in central South Bend, where vacancies are common, because capital values drop sharply when a market

Table 4

EQUIVALENT RENT MULTIPLIERS FOR SINGLE FAMILY HOMES

Year of Construction	Ratio of Gross Rent to Capital Value[a]		
	St. Joseph County		Brown County
	Central South Bend	Rest of County	
Post-1944	.2404	.1814	.1253
1915-1944	.2474	.1884	.1323
Pre-1915	.2573	.1983	.1422

SOURCE: Calculated by HASE staff from records of the baseline landlord surveys, Brown and St. Joseph counties.

[a]Actual averages of rent-value ratios for the nine cells above were smoothed according to the following equation:

$$\text{Multiplier} = .1253 + .1151\,(CSB) + .0561\,(ROC) + .0070\,(1915\text{-}1944) + .0169\,(\text{Pre-}1915),$$

estimated by ordinary least squares. The independent variables are dummy variables for central South Bend (CSB), rest of St. Joseph County (ROC), and year of construction. The smoothing assumes independent and additive location and age effects. See Rydell, 1977, Tables A.2 through A.4, for unsmoothed data and sample sizes.

loosens but rents drop relatively little.* The multipliers are larger for older units, because older units require more maintenance. The prospect of higher operating costs for older units is capitalized, causing lower market values even though the units command the same rent as newer ones with the same amount of physical capital.

To estimate equivalent gross rent for owners, the multipliers in Table 4 were applied to the pooled estimate of capital value of owner-occupied units,** stratified by location in St. Joseph County and by age of unit in both counties.

Other variables in the analysis classify households by location, household type (combination of age and family composition), household size, and race of household head. The precise definitions of those variables are given in Sec. III.

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*For an explanation of that phenomenon, see Rydell, forthcoming.

**The pooled estimate is the geometric mean of owner estimate and equalized assessed value, where the equalization rate was chosen to make the sum of equalized assessed values of sampled dwellings in a taxing district equal to the sum of owners' estimates.

III. A CONSTANT ELASTICITY MODEL

SPECIFYING THE MODEL

The quantity of housing demanded (Q) is a function of income (Y), the relative price of housing (P), and a vector of other household characteristics (Z):

$$Q = f(Y,P,Z) \tag{1}$$

Data on the quantity of housing are not available, but rental expenditures and market values are. Multiplying Eq. (1) by the price of housing transforms it into expenditure terms:

$$E = g(Y,P,Z) \tag{2}$$

where E is expenditures on housing.

The price of housing is equally difficult to measure, because identifiable units are not traded. If price and income are correlated, omitting price or measuring it with error biases the estimate of η. As Sec. I discussed, multicity estimates are likely to be biased upward and are more likely to suffer from unmeasured price variation than single-city estimates.

But single-city estimates are not guaranteed to be free of bias if price is omitted. Polinsky argues that single-city estimates are probably biased downward because housing is price inelastic and price and income are negatively correlated (high income households locate in suburbs where land rent, hence price, is low).* Neither HASE site exhibits the strong, negative price gradient with distance from center hypothesized by Polinsky. In fact, the flow price of housing in central South Bend is lower (by about 2 percent), not higher, than in the rest of St. Joseph County.** The price of housing could correlate

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*See Polinsky, 1977.

**The flow price discount is small, but capital values are discounted some 40 percent in central South Bend (see Rydell, 1977,

with income for other reasons, but the Brown County renter hedonic index revealed essentially zero correlation between price and income in that sample.*

If income and the price of housing are uncorrelated, we can omit price from the explanatory variables, as in Eq. (3), without biasing the ordinary least squares estimate of η.**

$$ln(E) = a + b_1 ln(Y) + b_2 ln(H) + b_3 D_1 + b_4 D_2 + b_5 D_3 + b_6 D_4 + b_7 D_5 + b_8 D_6 + \varepsilon \quad (3)$$

where E = gross rent for renters, equivalent gross rent for owners;

Y = household income;

H = number in household;

D_1 = 1 for households with head younger than 30 and no children, 0 otherwise;

D_2 = 1 for households with head older than 61, 0 otherwise;

D_3 = 1 for households consisting of husband and wife with children and head 61 or younger, 0 otherwise;

D_4 = 1 for single-parent households, 0 otherwise;

D_5 = 1 for households with nonwhite head, 0 otherwise (included only in St. Joseph County equation);

D_6 = 1 for households located in central South Bend, 0 otherwise;

ε = error term assumed to be distributed $N(0,\sigma_\varepsilon^2)$.

---

p. 9). The price variation in St. Joseph County runs counter to the standard model of a negative price gradient from the center. Any such price gradient--which would probably be moderate in small metropolitan areas, such as the HASE sites--is swamped by the large demand loss experienced by central South Bend in the 1960s.

*If the hedonic index of rent on housing unit characteristics is correctly specified, the residual measures price variation. Regressing the normalized residual $([R - \hat{R}]/\hat{R})$, where R equals gross rent, on the logarithm of income, household type, and the logarithm of household size produced a coefficient of .011 on income with a standard error of .004. That coefficient implies that multiplying income by 2.72 (i.e., adding 1.0 to the logarithm of income) causes only a 1.1 percentage point increase in the price of housing. For a description of the hedonic index, see Barnett, forthcoming.

**The price of housing is implicitly included in the error term, ε.

Equation (3) was estimated for owners and renters in each site separately. The definitions of housing expenditures (E) and income (Y) were given in Sec. II. Household size and composition variables were included because they should affect housing decisions and are correlated with income, thus their omission would bias the estimate of η. Race of household head was included for St. Joseph County, which has a substantial minority population, but not for Brown County, whose population is 99 percent white. A dummy variable for location was included to capture the small price discount in central South Bend mentioned above.

CURRENT VERSUS PERMANENT INCOME ELASTICITIES

The single most debated issue in the literature on income elasticities for housing has been errors in measuring income. The interpretation of η as longrun change in expenditures caused by a change in income implies a particular E,Y pair: E is the expenditure a household would choose if it made a housing consumption choice at the time of observation and Y is the income the household considers in making the choice.

Observed E,Y pairs suffer from two problems: (1) although actual E can be measured fairly accurately, it may not be the E a household would choose if it were dislocated and forced to make a new consumption decision, and (2) households probably consider a longer income time horizon than one year when making a choice. As long as the measurement error in E is random (i.e., households consuming more than their equilibrium E are balanced by underconsumers), estimates of η are unbiased.* However, random measurement error in the independent variable Y biases the estimate of η downward; therefore, measurement of Y deserves more attention.

Measurement error in Y consists of reporting error and using an improper accounting period. HASE income data are collected in great

*Estimates of η using recent movers, who are presumably consuming their equilibrium E, were essentially identical to those for all households, suggesting that bias in E is not a serious problem.

detail by trained interviewers in person-to-person interviews; therefore, they are probably at least as accurate as other income data.* Averaging three years of income approximates the time horizon and construction of permanent income suggested by Friedman; it also smoothes out the large year-to-year fluctuations in income that some households experience.**

A comparison of the first and last columns of Table 5 shows that permanent income elasticity estimates are substantially larger than current income estimates (37 percent for owners and 62 percent for renters). The sign of the difference is as expected, and the support of the research community for the permanent income concept is strong. But the permanent income sample is much smaller (see Table 2) and contains a different distribution of household types (mainly older heads) than the current income sample, raising the question of whether the permanent income estimate is applicable to the general population.

To test for differences, we compare the middle two columns of Table 5--the elasticity estimate for households in the permanent income sample (nonmovers) versus the estimate for households not in that sample (movers). The estimates are based on current income, the only income measure common to both samples.

Most speculation and some empirical evidence suggest that mover elasticities should exceed nonmover elasticities.*** The results of

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*HASE income data are before taxes. If the tax system were progressive, after-tax income would produce higher elasticity estimates. Break and Pechman, 1975, p. 10, find that "average federal tax burdens are either proportional to income or slightly progressive, depending on the assumptions made about the incidence of the corporation profits tax." Errors in estimating a household's tax liability would probably outweigh benefits of accounting for taxes in a system that is at most slightly progressive; therefore, HASE income data were not adjusted for estimated taxes.

**Friedman, 1957, found evidence that consumers have a multiyear time horizon on income for their consumption decisions. Uncertainty as to the appropriate relative weights of the years remains, but estimates of η from both HASE data and the Panel Study of Income Dynamics data (Carliner, 1973) were insensitive to alternative weighting schemes.

***de Leeuw, 1971, p. 5, argues that movers move because they have higher income elasticities than nonmovers. Carliner, 1973, using four-year average income from the Panel Study of Income Dynamics,

Table 5

COMPARISON OF CURRENT AND PERMANENT INCOME ELASTICITIES

Site and Tenure	Estimated Income Elasticity, by Sample			
	Current Income Sample		Permanent Income Sample	
	All Cases $\hat{\eta}(Y_c)$	Cases Not in Permanent Income Sample $\hat{\eta}(Y_c)$	$\hat{\eta}(Y_c)$	$\hat{\eta}(Y_p)$
Brown County:				
Owner	.383	.338	.450	.513
	(.034)	(.037)	(.053)	(.058)
Renter	.119	.108	.166	.219
	(.010)	(.011)	(.023)	(.028)
St. Joseph County:				
Owner	.283	.301	.261	.395
	(.042)	(.058)	(.065)	(.073)
Renter	.108	.106	.129	.152
	(.012)	(.013)	(.036)	(.038)

SOURCE: Equation (3) estimated with data from current and permanent income samples.

NOTE: The current income sample consists of all households with complete baseline records; the permanent income sample consists of the subset who also have complete records for the two following years. Cases in the current income sample but not in the permanent income sample are primarily households that moved after baseline. Cases in the permanent income sample are nonmovers.

The elasticity estimates ($\hat{\eta}$) are either for current income (Y_c) or permanent income (Y_p). Standard errors are in parentheses.

Table 5 are mixed. The nonmover estimate is higher in three cases, whereas the mover estimate is higher in only one case. Although these point estimate comparisons contradict popular beliefs, in no case are the differences statistically significant at the 95 percent level.

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estimated mover elasticities to be 13 percent (owners) and 16 percent (renters) greater than nonmover elasticities, although the differences were not statistically significant.

Moreover, the comparison probably overstates the elasticity of nonmovers relative to movers because of differential biases from using current income. Using current income biases both mover and nonmover estimates downward, but if nonmovers have more stable income, then their current income better measures their permanent income and the downward bias is less for them.

We cannot detect mover-nonmover differences in η with HASE data, but we suspect them. Carliner, who was able to do the mover-nonmover comparison with permanent income because he had data on a panel of households, found mover elasticities slightly, but not statistically higher. We conclude from this evidence that the permanent income sample underestimates the population elasticity by a small but unknown amount. The nonmover estimate using permanent income is, however, almost certainly a better estimate of mover elasticities than the current income elasticity for movers, because although it is probably biased downward, it is still larger than the current income estimate.

OWNER VERSUS RENTER ELASTICITIES

The cross-site differences in estimated elasticities (last column of Table 5) are not statistically significant, but the owner-renter differences are. The average estimated owner elasticity (0.45) is much greater than the average renter estimate (0.19).

A positive owner-renter elasticity difference is plausible. Owners receive an income tax advantage from deductible mortgage interest. A given interest deduction is worth more to high than to low income owners because they are in a higher tax bracket.* Owners also have equity in their homes, which makes housing an investment as well as a consumption good. The tax-shielded return on an owner-occupied home** will have increasing appeal with increasing income, again because of progressive tax brackets.

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*The tax advantage should be treated as a price discount if modeled explicitly. Since it was not modeled in this study, it affects the estimated income elasticity.

**Imputed return on equity and appreciation of capital value are not taxed until sale. Then the tax is at the lower (than income) capital gains rate, or no tax is owed because a new home is purchased.

Although most other researchers also estimate owner elasticities greater than renter elasticities, the ratio of owner-renter estimates with HASE data (2.5) is much larger than that in the literature (1.5). Perhaps downward bias in our renter estimate, upward bias in our owner estimate, or both inflate the difference.

At least three possibilities of downward bias in the renter estimate come to mind. First, the permanent income sample of nonmovers probably biases the estimate downward, as discussed earlier in this section. Second, three-year average annual income may vary more than true permanent income--i.e., measurement error persists in an independent variable. Finally, because the renter population is a self-selected sample from the total population--consisting of those who choose to rent rather than to own--estimating the elasticity for renters alone could lead to biased estimates if the probability of renting is correlated with housing expenditures.* The latter two sources of potential bias could not explain the difference between this report's estimates and the literature, since most studies use a similar definition of permanent income and do not correct for selection bias.

Potential biases in owner elasticity estimates arise from using a function of capital value as the measure of housing expenditures. If the constant rent multiplier k oversimplifies the relationship between expenditures (E) and market value (V), bias can result. For example, if E/V decreases with increasing V, the estimated elasticity (using $E/V = k$) will be biased upward. We stratified the sample of single-family houses by age and market condition to control for likely variation in E/V, thus alleviating, if not eliminating, this potential problem.

Including imputed income from equity (equity equals capital value minus debt) in an independent variable (income) and using a multiple

---

*If there existed a cutoff in housing expenditures, above which everyone became an owner, we would expect to see renter elasticities decline with increasing income. Tests for η varying with income showed either no variation or a slight increase in η with income (see Sec. IV). Furthermore, Lee and Trost, 1978, find virtually no difference between OLS estimates of the income elasticity and those estimated with a model that accounts for the simultaneous determination of tenure and housing expenditures.

of capital value as the dependent variable causes income to be positively correlated with the error term in Eq. (3), because errors in measuring the capital value of houses appear with the same sign in the income and the error terms. That positive correlation causes an upward bias in the elasticity estimate.

Imputed equity belongs in Eq. (3); removing it would bias the elasticity estimate downward because of the error introduced in the income variable. Estimating Eq. (3) with imputed equity removed from income produces a lower bound on the elasticity (an upper bound on the bias caused by this problem). The lower bounds are 0.288 (St. Joseph County) and 0.408 (Brown County), substantially less than the 0.395 and 0.513 in Table 5. But even the average lower bound owner estimate (0.35) is considerably greater than the average renter estimate (0.19).

The biases that may arise because capital value appears in the dependent variable are best solved by measuring the desired dependent variable--quantity of housing--with an hedonic index, not by altering independent variables. Unfortunately, hedonic quantity measures were not available for owner-occupied dwellings for this analysis.

FULL CONSTANT ELASTICITY MODEL WITH PERMANENT INCOME

Table 6 presents the estimated coefficients from Eq. (3) for Brown and St. Joseph counties by tenure. The estimated income elasticities (coefficient of $ln(Y)$) were discussed in previous subsections.

Household size is significant for renters but not for owners. Perhaps the longer stays of owners accounts for the absence of a household size effect for them. Owners may buy larger places than they need in anticipation of additions to their household and stay in larger places than they need when household size decreases. Large transaction and moving costs would make anticipation and infrequent adjustment the optimal strategy.

For renters, household size considerably influences housing expenditures. In St. Joseph County, doubling household size causes E to increase 18 percent, whereas doubling income causes only an 11 percent increase. In Brown County, the numbers are 5 percent for household size versus 16 percent for income.

Table 6

REGRESSION OF HOUSING EXPENDITURES ON INCOME AND HOUSEHOLD CHARACTERISTICS: CONSTANT ELASTICITY MODEL

Independent Variable		Brown County		St. Joseph County	
Description	Symbol	Owners	Renters	Owners	Renters
Logarithm income	$ln(Y)$	.513[a] (.058)	.219[a] (.028)	.395[a] (.073)	.152[a] (.038)
Logarithm household size	$ln(H)$	-.131 (.067)	.076[b] (.038)	-.101 (.084)	.243[a] (.052)
Young	D_1	-- --	.029 (.042)	.301 (.181)	.095 (.069)
Elderly	D_2	.146 (.075)	.029 (.044)	.086 (.088)	-.030 (.061)
Couple with children	D_3	.144 (.084)	.038 (.059)	.060 (.104)	-.105 (.085)
Single parent	D_4	.293 (.175)	.179[a] (.061)	-.046 (.154)	-.055 (.077)
Nonwhite	D_5	(c) (c)	(c) (c)	-.141 (.105)	.027 (.049)
Central South Bend	D_6	(c) (c)	(c) (c)	-.100 (.069)	.015 (.041)
Intercept		.509	2.767	1.961	3.392
Sample size		220	404	179	196
$\bar{R}^2$		.32	.27	.24	.35
Standard error of estimate		.305	.263	.373	.251

SOURCE: Equation (3) estimated with data from the household and landlord surveys, Brown and St. Joseph counties, baseline through wave 3.

NOTE: Standard errors of coefficients in parentheses.

[a]Coefficient significantly different from zero at 99 percent confidence level using t-test.

[b]Coefficient significantly different from zero at 95 percent confidence level using t-test.

[c]Variable not included in Brown County regressions.

The positive effect of household size was expected, but in St. Joseph County its influence compared with that of income is surprising. The low income elasticity of renters coupled with their sensitivity to household size suggests that they spend whatever is necessary to get adequate space but embellish the basic housing very little as their incomes rise.

Controlling for income and household size, stage in the life cycle--D_1 to D_4 in Table 6--seems to little affect housing expenditures. Only in Brown County, where single-parent renter households spend more than the reference group of middle-aged households without children, is any life-cycle variable statistically significant at the 95 percent level.

Adding interaction terms between income and household size, type, and race tests whether η varies with household characteristics.* Interactions added to the explanatory power (measured with an F-test) of Eq. (3) in three of the four samples. Multicollinearity problems hinder statistical inferences about whether the interactions matter at all, and, if they do, which ones are significant. One plausible interpretation of the results is that elderly, nonwhite, and large households spend more on housing than others** but increase housing expenditures at a lower rate as their incomes increase--i.e., they have lower income elasticities. Conclusive findings would require larger sample sizes in the various strata of interest.

The estimates of η in Table 6 fall below almost every published estimate of the last decade. The upper confidence limits on the estimates for owners are above the lower bounds in the literature, but the renter estimates are below the range in the literature by any method of comparison.

Is a renter elasticity of 0.19 reasonable? We have suggested that it is probably biased downward, but identifiable biases seem to be small. It is worth asking what the HASE data would have to look

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*See Appendix B for the details of those tests.

**When interaction terms for elderly and nonwhite were entered, the coefficient on the dummy variable for those groups became significant and positive for some samples where it was insignificant in Table 6.

like to be compatible with a higher renter elasticity or, conversely, just how incompatible with higher estimates they are.

Figure 1 shows Eq. (3) estimated with HASE data (solid line) and with η set arbitrarily to 0.3 and 0.4 (dashed lines). Those lines are superimposed on a plot of the actual data averaged over income intervals; for each data point the standard error of E is shown.* Although the monthly gross rents implied by an elasticity of 0.4** seem reasonable, they are not compatible with HASE data. In both counties, the $\eta = 0.3$ line is beyond one standard deviation around the data points at income extremes, and the $\eta = 0.4$ is out of the range of the data almost everywhere.

This section assumed that the constant elasticity model, Eq. (3), was correct. Section IV compares Eq. (3) with other functional forms, focusing on the possibility that η varies with income.

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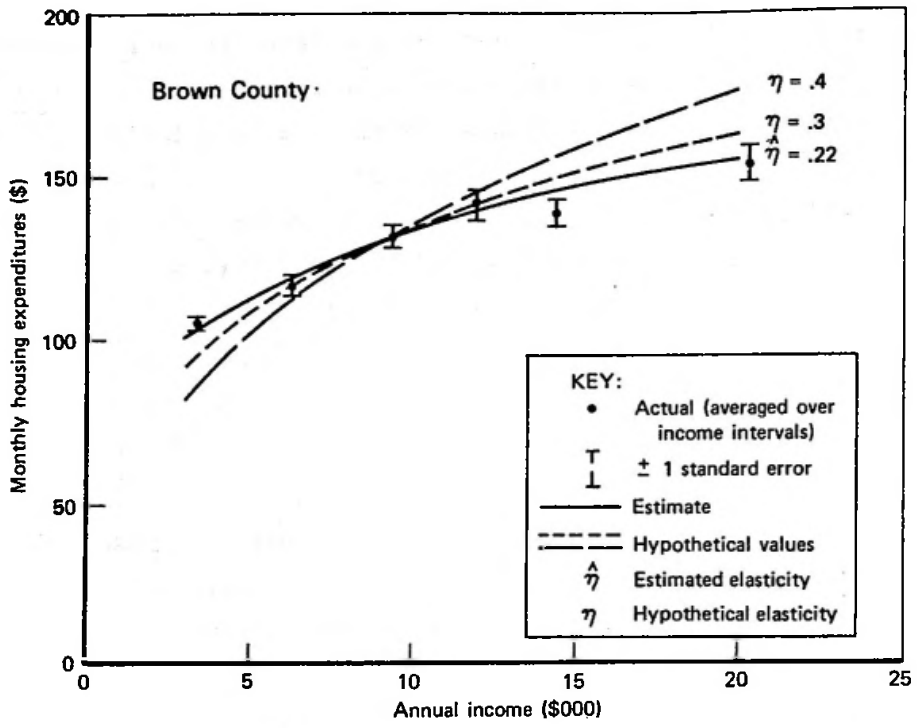
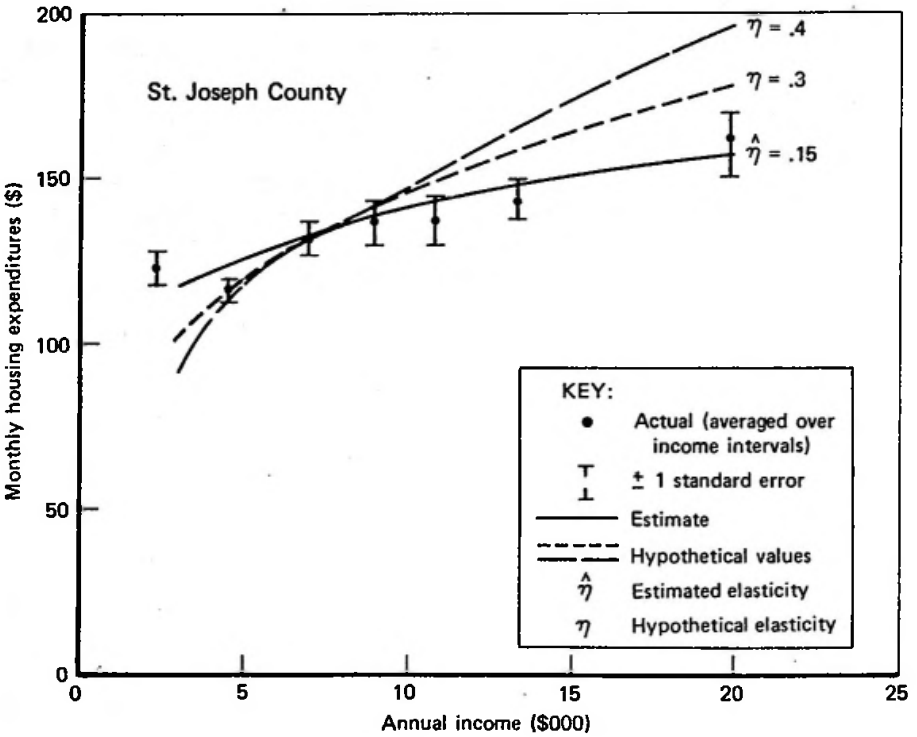
*The actual data and estimated Eq. (3) are plotted in E,Y space by fixing the other independent variables at their mean values. In symbolic notation: Writing Eq. (3) as $ln(E) = bln(Y) + cZ$, subtract cZ and add $c\bar{Z}$ to each side, yielding $ln(E) - cZ + c\bar{Z} = bln(Y) + c\bar{Z}$. In Fig. 1, the ordinates of the data points are $ln(E) - \hat{c}Z + \hat{c}\bar{Z}$, and the ordinates of the predicted equation are $\hat{b}ln(Y) + \hat{c}\bar{Z}$.

**The lines for hypothetical elasticities in Fig. 1 were constructed by forcing them through the mean values of adjusted E (adjusted to the mean values of the nonincome independent variables) and Y to compute α in $E' = \alpha Y^{\eta}$, where E' = adjusted E.





SOURCE: Equation (3) estimated with data from the household and landlord surveys, Brown and St. Joseph counties, baseline through wave 3.

Fig. 1— Renter housing expenditures versus income: actual data, constant elasticity model estimates, and hypothetical elasticities

IV. VARIABLE ELASTICITY MODELS

Neither theory nor historical observation precludes η from varying with income, yet the constant elasticity model has dominated the literature. This section compares the constant elasticity model with several models in which η can vary with income.

The estimate of η in the constant elasticity specification (Eq. 3) is simply the coefficient of $ln(Y)$. Perhaps such computational simplicity has attracted researchers to that form, but it has other benefits as well. Because housing expenditures and especially income are highly skewed distributions and because one can expect the absolute variation in expenditures to be larger at higher incomes, the constant elasticity specification, with its lognormal error term, is an obvious way to avoid heteroscedasticity.

The main competing functional form has been the linear model*

$$E = a + bY \tag{4}$$

in which the income elasticity is

$$\eta = \frac{\partial E}{\partial Y}\frac{Y}{E} = \frac{bY}{E} \tag{5}$$

For $a > 0$, the income elasticity is zero at $Y = 0$ and increases toward $\eta = 1.0$ as Y approaches infinity.**

The linear form assumes that the marginal propensity to consume housing (MPC) is constant as income increases, whereas the constant elasticity model assumes that it decreases. The notion that housing

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*In this section's discussion, the models include only η and income terms to simplify and focus the exposition. However, each model was estimated with the same nonincome independent variables as Eq. (3).

**For $a = 0$, the elasticity is always unity. For $a < 0$, the elasticity goes from zero at $Y = 0$ to minus infinity at $a = bY$; it is positive for $a + bY > 0$ and increases to one as Y approaches infinity. Because no estimates of $a \leq 0$ appear in the literature, the discussion of the linear model assumes $a > 0$.

is a necessity suggests decreasing marginal propensity to consume, but the fact that housing is multidimensional and contains luxury components makes the hypothesis of a constant MPC (hence increasing η) plausible.

Both the constant elasticity and linear specifications impose restrictions on η; the former forces η to be constant and the latter forces η to increase with income. Two forms that allow either constant or changing η with income are the log-exponential and the spline.

The log-exponential specification transformed to its linear form is

$$ln(E) = a + b_1 ln(Y) + b_2 Y \tag{6}$$

The income elasticity from Eq. (6), $\eta = b_1 + b_2 Y$, changes linearly with income. We reject the hypothesis of constant elasticity (i.e., $\partial\eta/\partial Y = 0$) if $\hat{b}_2$ is significantly different from zero.

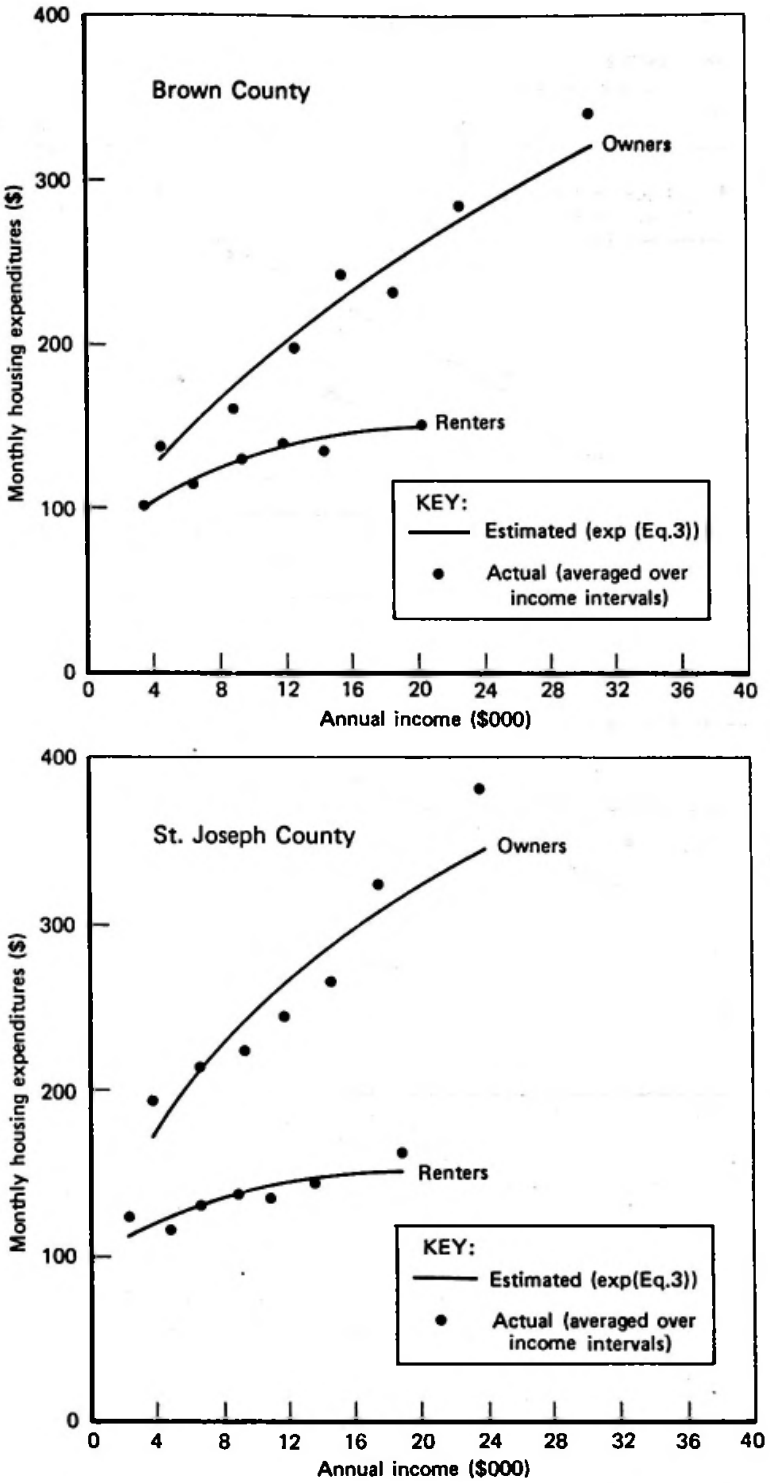
The spline function divides the income range into two or more intervals and estimates the constant elasticity model (Eq. (3)) in each, constraining E to be continuous at the interval boundaries. A two-interval spline function is

$$ln(E) = a + b_1 ln(Y) + b_2 D[ln(Y) - ln(C)] \tag{7}$$

where $D = 1$ if $Y \geq C$ and $D = 0$ if $Y < C$. The income elasticity in Eq. (7) takes two values: $\eta_1 = b_1$ for $Y < C$ and $\eta_2 = b_1 + b_2$ for $Y \geq C$. If $\hat{b}_2$ is significantly different from zero, we reject the hypothesis of constant elasticity.

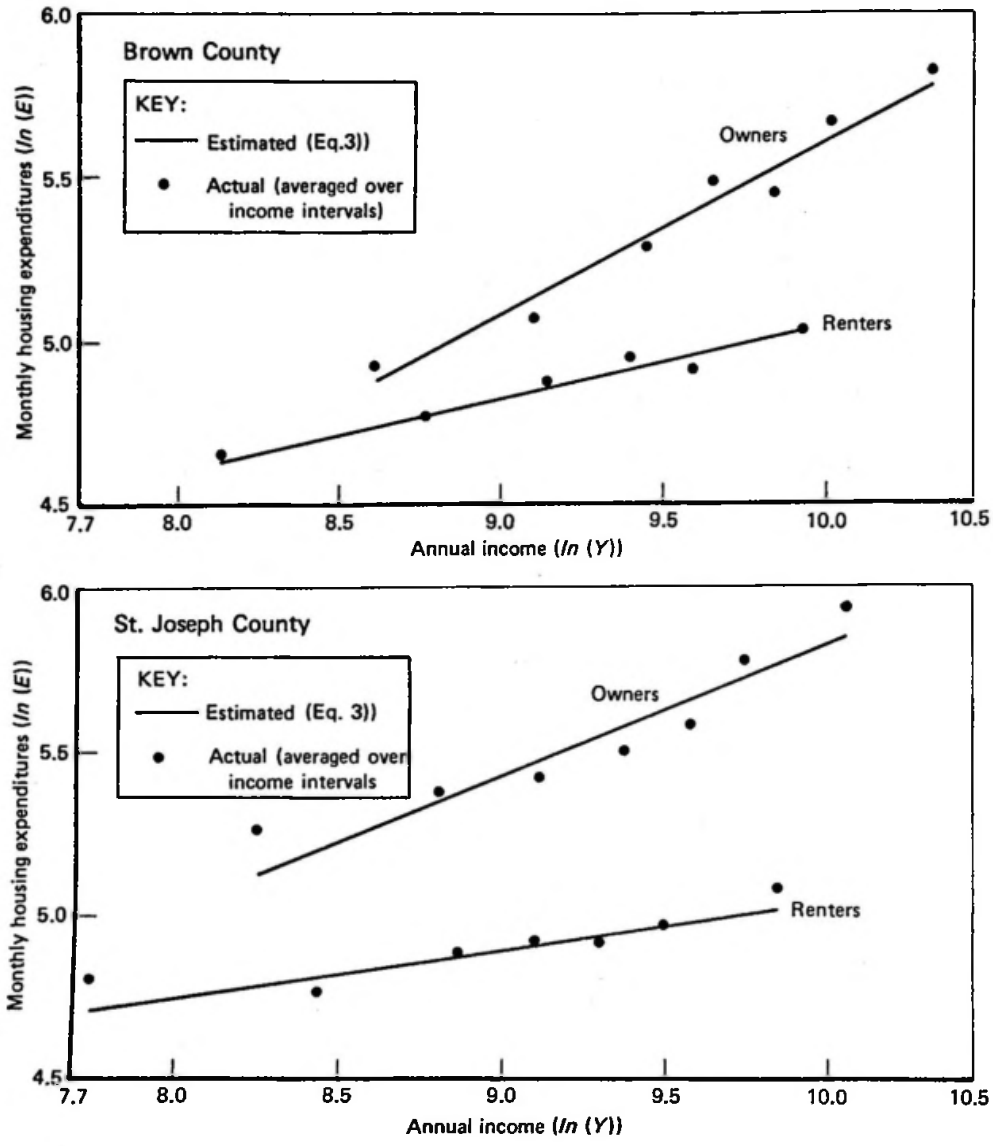
The models of Eqs. (3), (4), (6), and (7) were estimated with ordinary least squares for Brown and St. Joseph counties, owners and renters. Figures 2, 3, and 4 plot Eq. (3) (transformed and untransformed) and Eq. (4) in E,Y space, using the same technique as was used in Fig. 1.* Plotting the actual data and the estimated equation on

*Equations (6) and (7) were not plotted because $\hat{b}_2$ was significantly different from zero in only one of four cases. The estimated coefficients and their standard errors for those equations are given in Appendix C.



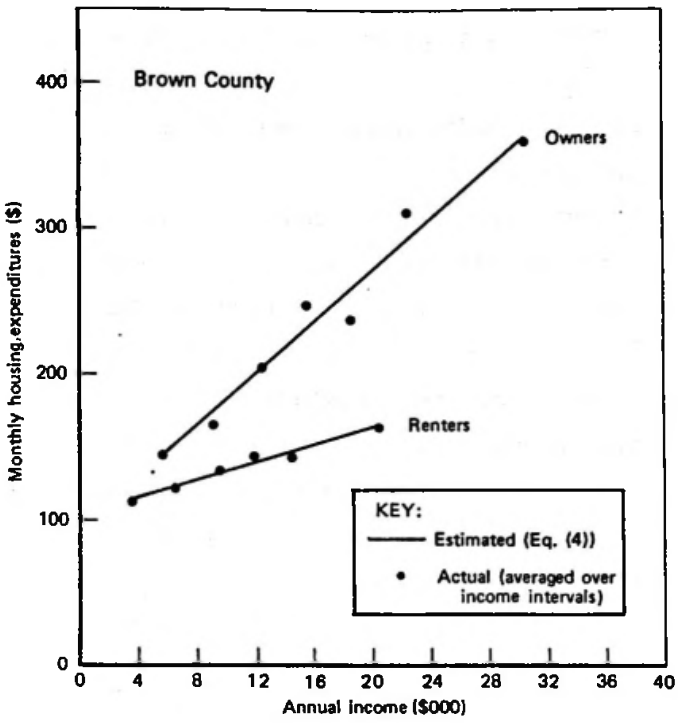
SOURCE: Equation (3) estimated with data from the household and landlord surveys, Brown and St. Joseph counties, baseline through wave 3.

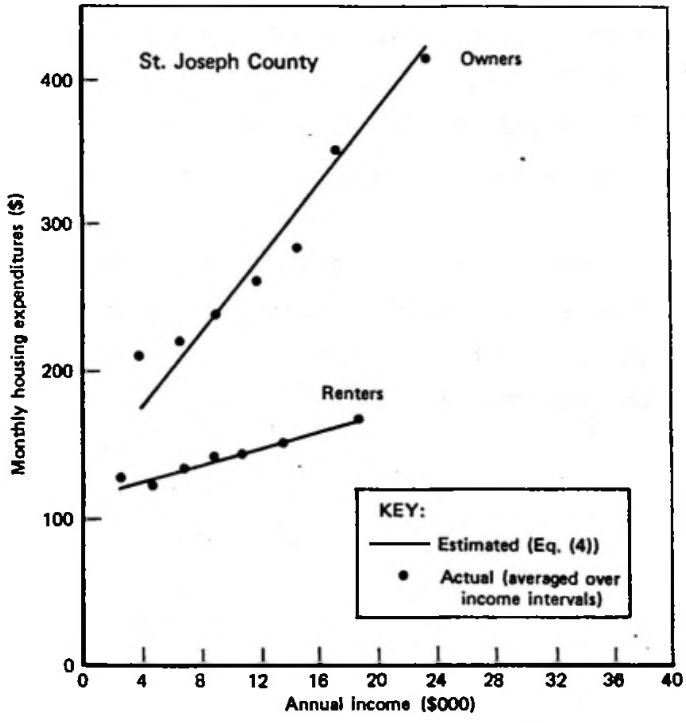
Fig. 2 — Housing expenditures versus income: actual data and constant elasticity model estimates



SOURCE: Equation (3) estimated with data from the household and landlord surveys, Brown and St. Joseph counties, baseline through wave 3.

Fig. 3 — Housing expenditures versus income: actual data and constant elasticity model estimates (logarithmic scale)





- SOURCE: Equation (4) estimated with data from the household and landlord surveys, Brown and St. Joseph counties, baseline through wave 3.

Fig. 4 — Housing expenditures versus income: actual data and linear model estimates

one graph shows both the functional form of the equation and specification error, if it exists.

The constant elasticity model, plotted in Fig. 2, fits the data well for all cases except St. Joseph County owners. The predicted curve tracks the data points well except for underpredictions at the highest incomes in the sample. Those large (in absolute terms) underpredictions result from the transformation of the model from logarithms back to E and Y.

Figure 3, which plots the constant elasticity model in its original $ln(E), ln(Y)$ space, shows that the data are consistent with the model.* The constant elasticity model minimizes the sum of squared percentage deviations in E; therefore, highliers get less weight than lowliers in the computation. Another way to see this is to observe that the model assumes that E has lognormally distributed errors; therefore, large positive residuals in E are given less weight because the distribution indicates they are less likely to occur.

Figure 2 strikingly portrays the differences between owners and renters implied by the estimated elasticities of 0.45 versus 0.19. The owners have much larger E's, a larger slope, and a range of incomes (designated by the range over which the curve is drawn) that overlaps but extends well above that of renters.

Figure 4 shows that the linear model also fits the data well. The predicted line comes close to the high-income data points because it minimizes the sum of squared arithmetic deviations of E. It needs no second figure to test the specification because it was estimated in E and Y.

The eye cannot distinguish the fits of Figs. 3 and 4, suggesting that the models are about equal over the bulk of the data. Table 7 confirms that message. The linear model produces lower $\hat{\eta}$'s than the constant elasticity model for low incomes and higher $\hat{\eta}$'s for high incomes, but the 95 percent confidence intervals overlap for all but the most extreme values of income, where very few observations lie.

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*The constant elasticity model was transformed and plotted in E,Y space (Fig. 2) to show functional form and display the magnitudes of owner and renter expenditures in familiar units.

Table 7

COMPARISON OF INCOME ELASTICITIES ESTIMATED FROM CONSTANT ELASTICITY AND LINEAR MODELS

Model and Data Base	Estimated Elasticity (η)		
	Lower Bound[a]	Point Estimate	Upper Bound[a]
Brown County			
Owners			
Constant Elasticity Model	.40	.51	.63
Linear Model, by Income ($)			
5,000	.24	.31	.38
10,000	.37	.48	.58
15,000	.45	.58	.70
20,000	.50	.64	.79
25,000	.54	.69	.85
Renters			
Constant Elasticity Model	.16	.22	.28
Linear Model, by Income ($)			
2,500	.06	.08	.09
5,000	.11	.14	.17
10,000	.19	.25	.30
15,000	.25	.33	.40
20,000	.31	.39	.48
St. Joseph County			
Owners			
Constant Elasticity Model	.25	.40	.54
Linear Model, by Income ($)			
5,000	.25	.34	.43
10,000	.38	.51	.64
15,000	.45	.58	.76
20,000	.50	.67	.85
25,000	.54	.72	.90
Renters			
Constant Elasticity Model	.08	.15	.23
Linear Model, by Income ($)			
2,500	.04	.06	.08
5,000	.07	.11	.16
10,000	.12	.20	.28
15,000	.17	.28	.39
20,000	.20	.34	.47

SOURCE: Equations (3) and (4), estimated with data from the household and landlord surveys, Brown and St. Joseph counties, baseline through wave 3.

[a]Approximate 95 percent confidence intervals were calculated for the linear model by assuming E = constant in $\hat{\eta} = \hat{b}Y/\hat{E}$. Since the relative error in $\hat{b}(s_{\hat{b}}/\hat{b})$ averages (across site and tenure) 7.4 times that in $\hat{E}(s_{\hat{E}}/\hat{E})$, $\hat{E}$ is nearly constant relative to $\hat{b}$, and the approximate confidence interval is $\hat{\eta} \pm (Y/\hat{E})s_{\hat{b}}$, where $s_{\hat{b}}$ is the standard error of $\hat{b}$ and $s_{\hat{E}}$ is the standard error of the estimate divided by the square root of the sample size in the regression of Eq. (4).

The models that can test for η varying with income cannot reject the hypothesis that η is a constant in three of four cases. But for St. Joseph County owners, the hypothesis of constant elasticity is rejected at the 95 percent confidence level in Eqs. (6) and (7), and other samples have point estimates indicating that η increases with income, although they are not statistically significant (see Appendix C).

Mixed evidence from Eqs. (6) and (7) and the equally good residual plots of Eqs. (3) and (4) leaves the question of whether η varies with income unsettled. The evidence is consistent with constant elasticity or elasticity increasing slightly with income.

V. CONCLUSIONS

This report's estimates of the longrun income elasticity of housing expenditures from cross-sectional HASE data are far below the benchmark of 1.0 that conventional wisdom and studies prior to 1971 had established and also well below most recently published estimates. The owner estimate (0.45) exceeds the renter estimate (0.19) by a large and statistically significant amount, although the difference is probably slightly overstated because of opposite biases in the estimates. Although the HASE estimates are based on data from only two housing markets, the data were unusually well suited to estimating income elasticities.

The results, if general, indicate that pure income transfers will not much affect recipients' housing expenditures. Nor would targeting the transfers by income level or household type significantly alter the expenditure effects, because income elasticities are either constant or increase slightly with income and they do not vary systematically with household type.

If income elasticity is constant with respect to income, housing expenditure increases caused by a given dollar program size would be slightly greater if the program were targeted on low-income households, because it would represent a larger percentage increase in their incomes. If the elasticity increases slightly with income, transfers would tend to produce the same housing expenditure effect regardless of the income level of subsidized households.

Targeting on homeowners would produce a larger expenditure effect than targeting on renters, because of owners' higher elasticities. But the full expenditure effect would be delayed, because large consumption changes are usually achieved by moving, and owners move much less often than do renters.

Some economists are skeptical of income elasticity estimates that are much below unity. By assuming that the typical budget share and the relative price of housing have been constant for decades while real income was rising, they infer approximately unitary elasticity.

Unfortunately, the price and budget share data needed to test the assumptions are not available. But the assumption that the relative price of housing has remained constant is suspect, because housing requires an input factor (land) whose supply is fixed and its production technology seems to have changed slowly relative to other technologies.

One factor that muddies the interpretation of income elasticities is their difference by housing tenure. Figures 2, 3, and 4 show that owners spend much more on housing than renters and also increase expenditures faster as incomes rise (i.e., have higher elasticities). Because we have estimated owner and renter elasticities separately, we cannot account for elasticity changes that accompany tenure changes. Averaging owner and renter elasticities would not explain the behavior of either.

Separate owner and renter elasticities are adequate for assessing the probable recipient expenditure effects of a housing allowance program such as HASE, because fewer than 5 percent of enrollees changed tenure during the first four years of program operation. The separate elasticities reflect the behavior of the 95 percent of enrollees that did not change tenure. Although not crucial to the policy conclusions of this report, future research might profitably consider the life-cycle dynamics of housing consumption, including tenure choice.

Appendix A

VARIABLE MEANS AND STANDARD DEVIATIONS: PERMANENT INCOME SAMPLE

Table A.1

VARIABLE MEANS AND STANDARD DEVIATIONS: PERMANENT INCOME SAMPLE

Variable		Brown County				St. Joseph County			
		Owners		Renters		Owners		Renters	
Description	Symbol	Mean	σ	Mean	σ	Mean	σ	Mean	σ
Monthly housing expenditure	*E*	230	98	131	38	287	138	137	41
Three-year average income	*Y*	15,298	6,982	9,387	5,260	12,778	6,246	8,275	5,132
Household size	*H*	3.98	2.11	2.50	1.75	3.10	1.74	2.61	1.82
Young	*D1*	0	0	.19	.39	.03	.17	.11	.31
Elderly	*D2*	.22	.42	.21	.41	.30	.46	.25	.43
Couple with children	*D3*	.62	.49	.26	.44	.41	.49	.22	.42
Single parent	*D4*	.02	.13	.12	.33	.05	.22	.22	.41
Nonwhite	*D5*	(*a*)	(*a*)	(*a*)	(*a*)	.09	.28	.23	.42
Central South Bend	*D6*	(*a*)	(*a*)	(*a*)	(*a*)	.29	.46	.58	.49

SOURCE: Tabulated by HASE staff from records of the surveys of households and landlords, Brown and St. Joseph counties, baseline through wave 3.

NOTE: Sample sizes are 220 Brown County owners and 404 renters; 179 St. Joseph County owners and 196 renters. σ = standard deviation.

[a]Variable not included in Brown County regressions.

Appendix B

INTERACTIONS BETWEEN INCOME AND HOUSEHOLD CHARACTERISTICS

Interaction terms were added to Eq. (3) to allow the income elasticity to differ by household type, household size, and race. For example, a simple interaction between young households (D_1) and income ($ln(Y)$) is tested by adding the term $b_9 D_1 ln(Y)$ to Eq. (3). The dummy variables for household type (D_i) were correlated with their associated interaction terms ($D_i ln(Y)$) at .99, because the pairs (D_i, $D_i ln(Y)$) cluster at $(0,0)$ and $(1, 9 \pm \sim 1)$. To reduce that high degree of collinearity, which can cause statistical packages to break down, we subtracted the mean of $ln(Y)$ from $ln(Y)$ for each observation. Table B.1 presents the results of interaction tests.

At least one interaction term is statistically significant in three of the four samples, but no systematic pattern emerges. An F-test shows that interaction terms add to the explanatory power of Eq. (3) for all but the Brown County owner sample.* Because of collinearity in the data, it is not clear which interaction terms matter, or if any are truly significant. Changing the mix of interaction terms in the equation changes their significance levels and can make all insignificant.

The mix of interactions reported for each sample in Table B.1 was chosen to maximize the number of significant interaction terms from the list in the stub of the table.** For Brown County owners, no combination of interaction terms produced any term that was statistically

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*The F-test is:

$$F(n,k) \cong \frac{[R^2 \text{ (with interactions)} - R^2 \text{ (without)}]/n}{[1 - R^2 \text{ (with)}]/k}$$

where n = number of interaction terms
and k = degrees of freedom in equation without interaction terms.

**Second and higher order interactions--e.g., race with household type and income--were not tested because sample sizes were judged too small to support them.

Table B.1

REGRESSION OF HOUSING EXPENDITURES ON INCOME, HOUSEHOLD CHARACTERISTICS, AND THEIR INTERACTIONS: CONSTANT ELASTICITY MODEL

Independent Variable		Brown County				St. Joseph County			
		Owners		Renters		Owners		Renters	
Description	Symbol	Coefficient	σ	Coefficient	σ	Coefficient	σ	Coefficient	σ
Logarithm income	$ln(Y)$	.394[a]	.129	.326[a]	.046	.635[a]	.151	.212[a]	.047
Logarithm household size	$ln(H)$	-.126	.067	.088[a]	.039	-.101	.086	.242[a]	.052
Young	D_1	--	--	.036	.047	.364	.379	.089	.068
Elderly	D_2	.209[a]	.086	.015	.048	.058	.091	-.010	-.061
Couple with children	D_3	.169	.085	.054	.063	.053	.118	-.050	-.088
Single parent	D_4	.281	.200	.134	.065	-.009	.155	-.075	-.077
Nonwhite	D_5	(b)	(b)	(b)	(b)	-.132	.105	.025	.049
Central South Bend	D_6	(b)	(b)	(b)	(b)	.112	.069	-.027	.041
$D_1[ln(Y) - \overline{ln(Y)}]$		--	--	-.118	.089	-.343	.653	(b)	(b)
$D_2[ln(Y) - \overline{ln(Y)}]$		.115	.143	-.143[a]	.067	-.399[a]	.151	(b)	(b)
$D_3[ln(Y) - \overline{ln(Y)}]$		-.262	.196	-.185[a]	.081	-.177	.237	(b)	(b)
$D_4[ln(Y) - \overline{ln(Y)}]$		-.289	.472	-.223[a]	.091	-.251	.413	(b)	(b)
$D_5[ln(Y) - \overline{ln(Y)}]$		(b)	(b)	(b)	(b)	-.429[a]	.176	(b)	(b)
$ln(H)[ln(Y) - \overline{ln(Y)}]$		.208	.113	(b)	(b)	.090	.149	-.135[a]	.062
Intercept		1.62		1.80		-.319		2.88	
Sample size		220		404		179		196	
F-value		1.05		2.43[c]		2.21[c]		4.72[c]	
R^2		.32		.28		.27		.37	
Standard error of estimate		.304		.261		.365		.249	

SOURCE: Estimated with data from the household and landlord surveys, Brown and St. Joseph counties, baseline through wave 3.

NOTE: σ = standard error.

[a]Coefficient significantly different from zero at 95 percent confidence level using t-test.

[b]Variable not included in regression.

[c]Significant at 95 percent confidence level.

significant. However, the dummy variable for elderly was pushed over the significance threshold by inclusion of interactions (compare with Table 6).

For Brown County renters, collinearity caused ambiguity. When all interactions were included, only the interaction of elderly with income was significant. When the interaction of household size with income was excluded, the single-parent and couple with children interactions with income became significant. When all household type interactions with income were excluded, the interaction of household size with income became significant. The correlation between the household size with income interaction term and the single-parent (.46) and couple with children (.77) interactions with income are too high to allow one to estimate their coefficients precisely with these sample sizes.

St. Joseph County owners gave the most stable result. Elderly and nonwhite interactions with income were significant in every combination tested, and no other interaction term was ever significant. For St. Joseph County renters, no interaction was significant when all were included, but household size interacted with income is significant when it is the only interaction term. Neither household type nor nonwhite interactions with income were ever significant.

Appendix C

LOG-EXPONENTIAL AND SPLINE MODEL RESULTS

Table C.1 presents results for the log-exponential model. In all samples, the point estimate of b_2 (coefficient of income) is positive, indicating that income elasticity increases with income. According to the point estimates, a $1,000 increase in annual income causes increases in η ranging from .002 (Brown County renters) to .048 (St. Joseph County owners). But only the St. Joseph County owner coefficient is significantly different from zero at the 95 percent confidence level, and its confidence interval is large. The other three samples cannot reject the hypothesis that η is constant (i.e., $\partial\eta/\partial Y = 0$).

Results for the spline model (see Table C.2) are similar to those for the log-exponential model. The point estimate of b_2 (coefficient of the spline shift term) is positive in all samples, indicating that η shifts upward at $Y = C$. Again, only the St. Joseph County owner coefficient is significantly different from zero; the other three samples cannot reject the hypothesis of constant elasticity.

Table C.1

REGRESSION OF HOUSING EXPENDITURES ON INCOME AND HOUSEHOLD CHARACTERISTICS: LOG-EXPONENTIAL MODEL

Independent Variable		Brown County		St. Joseph County	
Description	Symbol	Owners	Renters	Owners	Renters
Logarithm income	$ln(Y)$	.341[a]	.199[b]	-.158	.044
		(.152)	(.067)	(.166)	(.086)
Income ($000)	$Y/1000$	.012	.002	.048[b]	.014
		(.009)	(.007)	(.013)	(.010)
Logarithm household size	$ln(H)$	-.117	.077[a]	-.053	.246[b]
		(.067)	(.038)	(.082)	(.052)
Young	D_1	--	.031	.269	.095
		--	(.042)	(.174)	(.068)
Elderly	D_2	.125	.027	.049	-.036
		(.077)	(.044)	(.085)	(.061)
Couple with children	D_3	.139	.039	.046	-.098
		(.084)	(.059)	(.100)	(.085)
Single parent	D_4	.285	.179[b]	-.033	-.043
		(.174)	(.061)	(.149)	(.077)
Nonwhite	D_5	(c)	(c)	-.148	.025
		(c)	(c)	(.101)	(.049)
Central South Bend	D_6	(c)	(c)	-.110	-.012
		(c)	(c)	(.067)	(.041)
Intercept		1.97	2.93	6.49	4.22
Sample size		220	404	179	196
$\overline{R}^2$		.32	.27	.29	.36
Standard error of estimate		.304	.263	.360	.251

SOURCE: Equation (6) estimated with data from household and landlord surveys, Brown and St. Joseph counties, baseline through wave 3.

NOTE: Standard errors of coefficients in parentheses.

[a]Coefficient significantly different from zero at 95 percent confidence level using t-test.

[b]Coefficient significantly different from zero at 99 percent confidence level using t-test.

[c]Variable not included in Brown County regressions.

Table C.2

REGRESSION OF HOUSING EXPENDITURES ON INCOME AND HOUSEHOLD CHARACTERISTICS: SPLINE MODEL

Independent Variable		Brown County		St. Joseph County	
Description	Symbol	Owners	Renters	Owners	Renters
Logarithm income	$ln(Y)$	.431[a] (.174)	.219[b] (.042)	.100 (.107)	.088 (.058)
Spline shift term	$D[ln(Y) - ln(C)]$[c]	.152 (.098)	.0004 (.083)	.646[b] (.178)	.166 (.112)
Logarithm household size	$ln(H)$	-.122 (.067)	.076[a] (.038)	-.060 (.082)	.250[b] (.052)
Young	D_1	-- --	.029 (.042)	.247 (.175)	.092 (.068)
Elderly	D_2	.127 (.077)	.029 (.044)	.049 (.085)	-.037 (.061)
Couple with children	D_3	.143 (.084)	.038 (.059)	.043 (.101)	-.106 (.084)
Single parent	D_4	.290 (.174)	.179[b] (.061)	-.019 (.149)	-.047 (.077)
Nonwhite	D_5	(d) (d)	(d) (d)	-.142 (.102)	.025 (.049)
Central South Bend	D_6	(d) (d)	(d) (d)	-.111 (.067)	-.010 (.041)
Intercept		1.25	2.77	4.55	3.92
Sample size		220	404	179	196
$\overline{R}^2$		.32	.27	.29	.36
Standard error of estimate		.305	.263	.360	.250

SOURCE: Equation (7) estimated with data from household and landlord surveys, Brown and St. Joseph counties, baseline through wave 3.

NOTE: Standard errors of coefficients in parentheses.

[a]Coefficient significantly different from zero at 95 percent confidence level using t-test.

[b]Coefficient significantly different from zero at 99 percent confidence level using t-test.

[c]C is the income at which the income elasticity is allowed to shift. D is a dummy variable that equals 1 if $Y \geq C$; 0 otherwise. For Brown County, C = $13,000 (owner); $9,000 (renter). For St. Joseph County, C = $11,000 (owner); $8,000 (renter). The equation was estimated for values of C in the range $3,000–$20,000 ($1000 increments), and the value that minimized the standard error of estimate was chosen.

[d]Variable not included in Brown County regressions.

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