RESEARCH IN URBAN ECONOMICS

A Research Annual

Editor: J. VERNON HENDERSON
Department of Economics
Brown University

VOLUME 2 • 1982

JAI PRESS INC.

Greenwich, Connecticut *London, England*

CONTENTS

THE DETERMINANTS OF HOUSING DEMAND

Eric A. Hanushek and John M. Quigley

I. INTRODUCTION

Housing consumption, particularly of the poor, has been the subject of active federal policy for the past half-century. During this period, a variety of subsidy mechanisms have been introduced to alter the housing choices of different groups in the population and to stimulate the construction of new dwelling units. While government subsidies have varied widely in form and have increased steadily (see Aaron, 1972; Bradbury and Downs, 1981), the key to understanding their welfare implications is knowledge of the basic parameters of housing demand and supply schedules. If policy makers had good estimates of the income and price elasticities of housing demand and the price elasticity of housing supply, they would be in a position to evaluate the welfare effects of most existing programs (cf. Murray, 1975) and to forecast the likely impact of many proposed housing subsidy programs (cf. Hanushek and Quigley, 1981).

Research in Urban Economics, volume 2, pages 221–242.

ISBN: 0-89232-212-8

However, after extensive empirical investigation, there remains considerable uncertainty about the basic parameters of supplier and demander behavior.

This chapter concentrates upon estimation of the demand parameters for housing. While this appears on the surface to be a straightforward application of consumer demand theory, certain distinctive features of housing markets make this problem qualitatively different, and its solution empirically more difficult, than in most applications. In particular, the multidimensional character of the housing "commodity" introduces important conceptual and measurement problems, beginning with simply the appropriate definitions of price and quantity consumed. Further, the significant transactions and adjustment costs required to modify housing consumption imply that individual households may adjust their consumption sluggishly. Thus, to understand the fundamental demand relationships, particularly the long-run implications of income or price changes, knowledge of the dynamic adjustment process is required. Together, these characteristics of the housing market imply that data generated by normal housing transactions provide less clear information about demand relationships than transactions data for most other consumer goods.

In this chapter, we report the results of an analysis of the income and price elasticities of demand for residential housing that recognizes these complications. The research reported below is based upon samples of longitudinal data originally gathered as a part of the Housing Allowance Demand Experiment (HADE).[1] The overall HADE research design is principally directed toward ascertaining the behavioral response of low-income-renter households to alternative forms of cash assistance—sometimes tied in particular ways to housing consumption. This analysis is not concerned, however, with the fundamental issues of housing policies or with the housing allowance experiments per se, but instead with estimation of the underlying demand parameters.[2] It capitalizes on two unique features of the data generated by the experiment: the panel aspect of the data and the experimental reduction in the price of housing that was introduced for one group of experimental households. These features permit the direct investigation of the price and income responsiveness of housing consumption in a dynamic context.

The following section of this chapter reviews briefly the literature on estimation of housing demand functions. Section III introduces the conceptual model, which distinguishes between short-run and long-run adjustment to changes in incomes, relative prices, and other economic conditions. Section IV presents the empirical analysis. The existence of longitudinal information on individual households and their choices allows an unusual opportunity to investigate the validity of the underlying conceptual model, since it permits the empirical model to be replicated for two time intervals for the same households in each of two very different local housing markets.

II. RESEARCH ON THE DETERMINANTS OF HOUSING DEMAND

The diversity of studies and the conflicting results on the "true" parameters (income and price elasticities) of the demand curve for housing services has generated at least three extended reviews of the literature (de Leeuw, 1971; Polinsky, 1977; and Mayo, 1978).

Most of the controversy surrounding estimates of the income elasticity of demand has concentrated upon the appropriate definition of income. Housing is a highly durable commodity and is expensive to modify; at the same time, the costs of moving are large. Presumably, therefore, households base consumption decisions on some "long-run" notion of income—and do not continuously adjust their housing to transitory fluctuations in income. This suggests that income elasticities based upon current income measures will understate the "true" income elasticity which appropriately reflects "long-run" (or "permanent") income.[3] This logic explains, in part, the divergence of elasticity estimates derived from individual household and aggregate market data, since average income from a market will better reflect "permanent" income.

Note, however, that the "permanent" income argument is really a statement about the dynamic adjustments of households. The implied adjustment behavior can only be made explicit by defining permanent income. For example, if permanent income is measured by a distributed lag of income, then a specific adjustment path of housing consumption to income changes is implied. However, the demand relationship may include other factors that affect housing consumption—such as family size, family composition, or workplace location. It seems equally reasonable to expect adjustment lags to changes in these factors which may be important determinants of demand. With respect to these other factors, there is no natural analog to "permanent" income, and the estimation of models that explicitly consider the dynamic behavior is appropriate. Importantly, the estimation of static models which include measures of long-run income, but do not consider other dynamic elements of housing demand, will *not* yield unbiased estimates of the income elasticity of demand unless long-run income is uncorrelated with the other characteristics that influence demand. If a measure of long-run income is correlated with other factors, the specification or measurement errors in these factors will affect the estimation of the income elasticity. In this case, however, it is not possible to indicate the direction of any bias.

The uncertainty surrounding the price elasticity of housing demand arises from the fact that housing prices are simply never observed at all in any cross section; only housing expenditures, i.e., prices times quantities, are observed directly. This has led researchers to estimate cross-sectional models of demand across housing markets and to relate average levels of housing consumption (i.e., total expenditures on housing) to estimates of the "average" cost for a "standardized" bundle (or quantity) of housing services in different regions or metropolitan areas. (See Fenton, 1974; de Leeuw, 1971; Carliner, 1973.) These price estimates are typically obtained from the City Workers' Family Budgets established by the Bureau of Labor Statistics (BLS) or, less commonly (cf. Muth, 1960), from indices of construction costs (e.g., the Boeckh index) obtained from industry surveys.

Neither of these measures of price variation is very satisfactory. The BLS data are gathered for an arbitrarily specified dwelling unit, and no attempt is made to control for differences in many of the important characteristics of housing which are surely reflected in market prices.[4] Construction cost indices are measures of labor and capital input costs for newly constructed dwelling units only and do not include land costs at all.

More important than the imprecision of such price indices, however, is the possibility of bias arising from intraarea price variation. For example, standard urban location models imply housing price gradients that, if ignored, would lead to biased estimates of price responsiveness. Polinsky (1977) considers this specific case and the statistical properties of price and income elasticity estimates of housing demand estimated from different types of data. He concludes that price elasticity estimates obtained from average metropolitan area housing price indices are likely to be biased away from zero.[5]

Only two papers have incorporated intrahousing market variation in housing prices into an analysis of price responsiveness (Muth, 1971; Polinsky and Ellwood, 1979).[6] These papers rely upon observations of individual dwelling units and households within, as well as between, housing markets to estimate the parameters of the demand curve. In both cases, a national sample of newly constructed FHA-mortgaged dwelling units is used to estimate the parameters of a (national) production function for housing (assumed constant elasticity of substitution). This allows computation of an estimated competitive unit price of housing, which can be used in a subsequent investigation of the price elasticity of demand.[7]

The estimation of the production function itself requires observations, not only of the metropolitan price of housing capital (both papers rely upon the Boeckh index), but also of the unit price of land which varies for each observation. For this crucial variable, the authors rely upon the unit price of land estimated by FHA appraisers. The reliability of these appraisals is dubious at best, but this is crucial to the analysis, since all intraurban variation in prices across dwelling units arises from variations in the price of land.

These estimates of price responsiveness are quite indirect and rely upon a series of strong assumptions 1) about the housing production function; 2) about the accuracy of land price data; and 3) about the homogeneity of demand relationships across areas. Nevertheless, they represent the most persuasive evidence on the price elasticity of housing demand developed so far; the point estimates are -0.67 to -0.70 for purchase of newly constructed units.

III. A MODEL OF HOUSING DEMAND DYNAMICS

With few exceptions, past research into the operation of housing markets has ignored dynamic considerations (see Muth, 1960, for an exception). Analyses of housing demand based upon aggregate data or cross sections of individual households are generally interpreted as equilibrium relationships. As we have stressed, however, the housing market is qualitatively different from the market for most economic commodities. There are typically large costs associated with transforming the housing services provided by any dwelling unit, and there are unusually high transactions costs incurred by households in changing their particular dwelling units.

These two facts provide the point of departure for investigating the sensitivity of housing consumption to variations in economic conditions. Since specific housing units are generally not very malleable (especially rental units, see Sweeney, 1974) and since the costs of searching, moving, security deposit, brokers fees, etc. plus any nonpecuniary costs of relocation are sizable (see de Leeuw and Ekanem, 1971), it follows that households' observed consumption of residential housing in any period may deviate significantly from their "equilibrium" levels of housing consumption—that is, the amounts of housing freely chosen in a frictionless world, given preferences, incomes, and relative prices. Although these considerations may be relevant for many goods, especially consumer durables, they are much more important quantitatively in the case of housing consumption.

Dynamic considerations and the timing of household adjustment are particularly salient in the interpretation of the HADE experiment, which for analytical purposes is only two years in duration. If dynamic adjustment is slow, as our previous analysis suggests (Hanushek and Quigley, 1979), then there is reason to expect that the observed housing consumption patterns of households at the end of the experiment will be misleading—at least if policy makers are interested in evaluating the long-term effects of experimental stimuli. Consideration of the long-run effects of short-term experiments requires some attention to market dynamics.

Let H^d_{t+1} represent the "desired" or equilibrium housing demand for a given household—that amount of housing freely chosen in a frictionless world, given preferences, prices, and incomes; let H_t be the observed housing consumption at time t. With well-behaved utility functions, the incentive to adjust housing consumption increases monotonically with the gap between observed and desired housing consumption during the interval $t \rightarrow t+1$, i.e., $[H^d_{t+1} - H_t]$.

The adjustment of consumption patterns by individual households can be characterized as a simple maximization problem and the solutions, depending on what elements one concentrates on, are fairly well known. For example, with fixed and known relocation costs and a two-period model, a given change in circumstances (such as a change in housing prices or a change in income) will induce a household to move to its new equilibrium consumption level if the change in utility measured in dollars between current housing consumption and equilibrium consumption exceeds relocation costs. Alternatively, if the prices of alternative dwelling units are unknown but follow a known distribution, the household will invest in search until the point where the expected utility gain from search equals marginal costs of search and will move if the utility change evaluated at the best price found in search exceeds relocation costs. Thus the consumption of housing for a given change in circumstances is probabilistically related to the distribution of prices.

The essential point in these conceptualizations is that the exact form of the dynamic response of households is related directly to the form of the underlying utility function and the distribution of prices and moving costs, elements which are generally unobserved. Nevertheless, for given distributions of search costs, transactions costs, etc., and for quite general utility functions, the expected adjustments of households to changes in circumstances or market conditions will be monotonically related to the gap between equilibrium consumption and current consumption of housing.

The empirical model concentrates upon a stock adjustment representation of consumption dynamics. In particular, a convenient and, as shown elsewhere (Hanushek and Quigley, 1979), a reasonable characterization of market demand dynamics is that households, on average, close the gap between desired and equilibrium housing consumption at a constant rate α, so that

$$H_{t+1} = \alpha[H^d_{t+1} - H_t] + \phi H_t, \tag{1}$$

where ϕ is 1 plus the rate of relative price increase during the interval.

This formulation need not necessarily describe the precise adjustments of individual households, but rather the overall responses of groups of households facing either exogenous or experimental changes in circumstances.[8]

A more general adjustment hypothesis is that households are more responsive to contemporaneous changes in desired levels of housing consumption than to their accumulated levels of disequilibrium. Since the principal method of changing housing consumption is through moving, which involves an investment in search, households may be more responsive in any period to changes in equilibrium demand than to their initial levels of disequilibrium. This is necessarily true, on average, if households search by sampling without recall from an unknown distribution. In this case, if an exogenous shock changes the level of disequilibrium, households will sample (search) and revise priors until the expected gain of an additional search is less than its cost. Thus an "unlucky" realization will result in less search activity and hence less observed adjustment activity in subsequent periods. To test this, the one-period disequilibrium can be decomposed, leading to a modified stock adjustment model:[9]

$$H_{t+1} = \beta[H^d_t - H_t] + \gamma[H^d_{t+1} - H^d_t] + \phi H_t, \tag{2}$$

with the hypothesis that $\gamma > \beta$. Equation (1), or the more general expression in Equation (2), indicates the expected intertemporal path of actual observed housing consumption, given the path of equilibrium housing demand.

Equations (1) and (2) describe the basic dynamics of consumption, where changes in equilibrium demand can arise from a variety of sources. It is useful for the subsequent empirical analysis to consider explicitly the case for which housing prices are experimentally reduced by some fraction η $(0 \leq \eta < 1)$. The new equilibrium housing demand $\bar{H}^d_t$ resulting from the price change is, by definition:

$$\bar{H}^d_t = H^d_t(1 + \epsilon\eta), \tag{3}$$

where ϵ is the price elasticity of demand for residential housing. Substitution into (1) and (2) yields

$$H_{t+1} = \alpha[H^d_{t+1} - H_t] + \alpha\epsilon\eta H^d_{t+1} + \phi H_t \tag{4}$$

and

$$H_{t+1} = \beta[H^d_t - H_t] + \gamma[H^d_{t+1} - H^d_t] + \beta\epsilon\eta H^d_t + \gamma\epsilon\eta[H^d_{t+1} - H^d_t] + \phi H_t. \tag{5}$$

Both formulations make explicit the lagged response to changes in housing circumstances or market conditions. For example, in Equation (4), increases in household income increase the equilibrium demand for housing, but in any given period the expected adjustment in observed housing consumption is only 100α percent. In a subsequent period the expected adjustment in housing consumption is $[100\alpha(1 - \alpha)]$ percent. Similarly, the long-run response to a change η in housing prices is measured by the price elasticity parameter times the price change $\varepsilon\eta$. However, on average, in the first period only 100α percent of this response will be observed. In Equation (5), a unit increase in housing demand in any period will result in an average adjustment of 100γ percent by the end of the period. In the subsequent period, the expected adjustment is $[100\beta(1 - \gamma)]$ percent. In Equation (5), if the true price elasticity is ε, after one period the observed response to a change in housing prices is $\gamma\eta\varepsilon$. After two periods the observed response is $[(\gamma + \beta - \beta\gamma)\eta\varepsilon]$.

IV. EMPIRICAL ANALYSIS

Virtually all past research into housing demand relationships can be viewed as attempts to estimate the equilibrium demand relationships. For a cross section of households within the same market, all households are viewed as facing the same set of prices, and expenditures are simply regressed upon the assumed determinants of variations in housing demand. To obtain estimates of price effects, samples of households across markets are used; the coefficient on the average housing price across markets is interpreted as the price responsiveness. As noted, this analysis has been further extended to incorporate intraarea price variations that arise from variations in land prices within areas and in capital prices between areas. In all cases, however, dynamic adjustments are ignored.

In contrast, Equations (4) and (5) explicitly incorporate dynamic responses arising from price or income changes or from changes in any other determinants of demand. The estimation strategy involves a two-stage procedure in which equilibrium demands are first estimated and then used as instruments in the estimation of the dynamic adjustment models. The first stage provides estimates of the effects of income and other (nonprice) determinants of demand at common initial prices; the instruments for equilibrium demand are used in the direct estimation of the adjustment models which indicate the responsiveness of households to price variations.

Equations (4) and (5) are similar to partial adjustment models that are frequently applied to other phenomena such as investment levels. Typically, empirical implementation involves first specifying the relationship between desired (or "equilibrium") consumption and a set of exogenous variables and then substituting this into the adjustment equation. The current activity level is estimated as a function of the exogenous factors and its lagged value. In the present application, an instrumental procedure is preferred for two basic reasons: 1) it may be unreasonable to assume that marketwide relative prices are constant during the time period of observation; and 2) the more complicated adjustments of Equation (5), coupled with the short time series available (i.e., longitudinal information for individual households is limited to three points in time), make such substitution infeasible. Therefore, we follow a strategy of direct estimation in which the equilibrium demand relationships are specified and estimated directly; these estimates, based upon a subset of households (discussed in Section IV.A, below), are used to form instruments for equilibrium demands for all sample households; the resulting instruments are used in the estimation of adjustment Equations (4) and (5) discussed in Section IV.B. As noted in Section IV.C, this procedure does introduce several statistical complications, but, with one exception, these complications are precisely the same as those encountered by the more common technique of direct substitution. Moreover, indirect evidence suggests that this instrumental technique provides a reasonable approximation of the underlying consumption behavior.

A. Equilibrium Relationships

Longitudinal data on individual households in the Pittsburgh and Phoenix housing markets are available at the three points in time. All sample households are renters with low annual incomes. A baseline survey was conducted for a large sample of households (at $t = 0$) prior to any experimental treatment. Households were subsequently assigned to a number of treatment groups and identical data were gathered after 12 months ($t = 1$) and, again, after another year ($t = 2$). This analysis is based upon a subset of all households initially interviewed and upon those households subsequently assigned to the control group or to treatment groups receiving price discounts at $t = 1$ and $t = 2$. At the time of the baseline data collection (or $t = 0$), we assume that all households in each housing market face the same prices for housing and other goods.[10] We further assume that those households recently making relocation decisions[11] choose to consume their utility-maximizing quantity of housing services, H^d. This is sufficient to identify the equilibrium demand equation at constant initial prices. These equations are estimated cross-sectionally for households within each housing market (normalized arbitrarily by setting the initial price of housing services to unity) by regressing housing expenditures on household income, assets, family size, and other demographic characteristics.

The estimated equilibrium demand relationships, discussed at length elsewhere (Hanushek and Quigley, 1978), are presented in Table 1. These demand functions follow a rather conventional specification except that: 1) considerable care is exercised in the specification of life cycle effects; and 2) the sample is confined to those households choosing equilibrium levels of housing services, identified by recent moving behavior.[12] The estimates reported rely upon stratification by age (below age 45 and 45 years or older for the head of household) along with linear age effects. Also included are variables reflecting the race, education, income, and

Table 1. Equilibrium Housing Demand Equations at Initial Prices for Recent Mover Households Stratified by Age[a]

Variable	*Pittsburgh* *Young*	*Pittsburgh* *Old*[b]	*Phoenix* *Young*	*Phoenix* *Old*[b]
Income (thousands of dollars)	4.020 (3.19)	4.920 (2.11)	6.290 (7.74)	5.660 (3.14)
Assets (thousands of dollars)	−1.310 (0.98)	1.118 (1.58)	1.230 (0.93)	1.230 (1.32)
Years of Education	4.950 (5.06)	1.318 (0.93)	3.647 (4.91)	0.600 (0.49)
Household Size	3.511 (1.27)	8.479 (3.65)	1.144 (0.94)	3.795 (1.49)
Black Household (1 = yes)	−15.383 (3.61)	−13.159 (1.56)	−25.541 (4.20)	−23.443 (0.41)
Other Nonwhite (Spanish) (1 = yes)	−14.93 (0.80)	−3.761 (0.11)	−16.370 (4.20)	−4.466 (0.41)
Age of Head (years)	1.403 (4.62)	0.450 (1.09)	1.312 (4.90)	−0.586 (1.47)
Refrigerator Included in Rent (1 = yes)	22.267 (2.89)	−13.272 (0.87)	−6.470 (1.40)	2.295 (0.23)
Stove Included in Rent (1 = yes)	1.074 (0.16)	25.063 (1.80)	22.926 (4.79)	−6.868 (0.57)
Air Conditioner Included in Rent (1 = yes)	[c]	[c]	15.488 (2.05)	27.616 (1.76)
Constant	1.283	32.408	7.418	104.907
R^2	0.318	0.359	0.315	0.247
Degrees of Freedom	313	91	502	128

Notes:
[a] t ratios in parentheses.
[b] Head of household aged 45 or more.
[c] Not included in regression.

assets of each household, as well as the terms of the rental contract for the provision of major appliances.

In general, the estimated demand functions are quite consistent with expectations and with previous empirical inquiries. In the linear form of the equilibrium demand relationships, the income elasticity varies with the level of income. Thus, a range of income elasticities can be calculated for comparision with alternative estimates of this parameter. Table 2 evaluates the estimated income elasticities at several points. The first two columns provide income elasticity estimates at the sample mean income and at the median Standard Metropolitan Statistical Area (SMSA) income. The SMSA estimates of income elasticities with respect to current income are somewhat higher than those obtained by others based upon individual data for renters—reflecting the restriction of the sample to recent movers. The last two columns provide estimates of the elasticity of demand with respect to "permanent income." These are obtained by relying upon exogenous information about the relationship between schooling and earnings in each metropolitan area. Note that current income (Y) includes a permanent (Y_p) and a transitory (Y_T) component; assume $E(Y_T) = \text{cov}(Y_p, Y_T) = 0$. The equilibrium demand equations in Table 1 take the form:

$$H^d = A_0 + A_1(Y_p + Y_T) + A_2ED + \cdots, \tag{6}$$

where ED is years of schooling. The elasticity of demand with respect to Y_p is then given by:

$$\varepsilon_{Y_p} = \frac{\partial H^d}{\partial Y_p} \cdot \frac{Y_p}{H^d} = \left[A_1 + A_2 \cdot \frac{1}{\partial Y_p/\partial ED}\right] \frac{Y_p}{H^d}. \tag{7}$$

To ascertain the relationship between permanent income and years of schooling separate estimates of a standard earnings function,

$$\log Y_p = b_0 + b_1ED + b_2EX + b_3EX^2 \tag{8}$$

Table 2. Alternative Estimates of Income Elasticities of Housing Demand

	Current Income *at* *Sample Mean*	*Current Income* *at* *SMSA Median*	*Permanent Income*[a] *at* *Sample Mean*	*Permanent Income*[a] *at* *SMSA Median*
Pittsburgh	0.15	0.58	0.55	1.02
Phoenix	0.23	0.56	0.51	1.13

Note:
[a] See text for derivation.

(where EX is experience), were made for male workers in the Pittsburgh and Phoenix SMSAs from the 1970 Public Use Sample (see Hanushek, 1981). For Phoenix b_1 is estimated to be 0.060, and for Pittsburgh b_1 is estimated to be 0.085. Substitution into Equation (8) yields the estimates of elasticities of housing demand with respect to permanent income reported in Table 2.

As suggested by others, the long-run income elasticities appear higher—on the order of 1.0 for the SMSA calculations.

Importantly for this analysis, the results reported in Table 1 provide a series of instruments for equilibrium demand and for changes in equilibrium demand over time. With annual information at $t=0$, 1, and 2 about household incomes and demographic characteristics, equilibrium demands at initial prices (i.e., H_0^d, H_1^d, and H_2^d) can be computed for each household.[13] This information, together with knowledge about experimentally induced reductions in housing prices and about actual housing consumption, permits estimation of both adjustment behavior and the price elasticity of housing demand—estimates which incorporate direct observations on experimentally induced variations in housing prices.

The observed housing expenditures of households (H_0, H_1, H_2) are normalized to eliminate an extraneous source of household price variations—those arising from duration of occupancy. Long-term occupancy by tenants can result in significant cost savings—not only from reduced redecorating expenditures but also from reductions in expected vacancy rates of rental units. In a competitive market, we would expect some or all of these savings to be passed on to tenants. Therefore, consumption expenditures are all normalized to new occupants, consistent with the equilibrium demand estimates in Table 1.[14]

B. Dynamic Adjustment and Price Elasticity Estimates

Estimation of the dynamic adjustment model and the price elasticity of demand relies upon the unique features of the HADE data: the longitudinal information for households and the experimental manipulation of housing prices. The analysis concentrates on 810 households in Pittsburgh and 618 households in Phoenix. After an initial home interview, 386 households in Pittsburgh (305 in Phoenix) were assigned to the control group which received no subsidies (i.e., $\eta=0$); the remaining households in each sample received rent rebates (η) which varied between 20 and 60 percent of their monthly rent (i.e., $\eta=0.2, \ldots, 0.6$).[15]

Table 3 presents coefficient estimates of the adjustment models, separately for households in the Phoenix and Pittsburgh housing markets. Within each housing market, the model is replicated in two successive 1-year intervals for the same sample of households. Assuming that the errors are normally distributed, the estimates are obtained by maximum-

Table 3. Estimates of Stock Adjustment Model of Housing Consumption for Experimental and Control Households[a]

$$H_{t+1} = \alpha\,[H_{t+1}^d - H_t] + \alpha\varepsilon\eta H_{t+1}^d + \phi H_t$$

	Pittsburgh			*Phoenix*		
	0->1	*1->2*	*Pooled Time Periods*	*0->1*	*1->2*	*Pooled Time Periods*
α	0.223	0.155	0.185	0.407	0.273	0.352
	(7.65)	(6.23)	(9.79)	(10.01)	(7.61)	(13.02)
ε	−0.573	−0.689	−0.642	−0.484	−0.385	−0.453
	(3.07)	(2.71)	(4.13)	(2.90)	(1.80)	(3.53)
ϕ	1.028	1.036	1.033	1.085	1.058	1.074
	(2.71)[b]	(3.77)[b]	(4.70)[b]	(5.02)[b]	(3.75)[b]	(6.39)[b]
R^2	.582	.700	.648	.535	.695	.610
Number of Observations						
Control	375	361	736	284	243	527
Experimental	424	407	831	302	265	567
Tests of Parameter Equality						
Control and Experimental Equality[c]	0.292	0.043		0.863	1.039	
Time Period Equality[c]			1.278			4.114

Notes:
[a] t-statistics in parentheses.
[b] t-statistic calculated on null hypothesis that parameter equals one; i.e., that there were no changes in the relative prices of housing and other goods.
[c] F-statistics.

likelihood techniques incorporating the nonlinear constraints on parameters.

Standard covariance tests suggest little difference in the estimated parameters in the two time periods.[16] Further, covariance tests indicate that the basic adjustment behavior of those households receiving experimental housing price reductions is no different from the behavior of control households who are unaffected by the experiment.[17]

The adjustment coefficient (α) indicates that, on average, 19 percent of the gap between desired housing consumption and observed initial consumption is closed in each 1-year period in Pittsburgh. In Phoenix, where the average mobility rate of households is higher, the results suggest that 35 percent of the gap is closed in any year.

In both housing markets, ϕ is significantly greater than 1, indicating

Table 4. Estimates of Expanded Stock Adjustment Model of Housing Consumption for Experimental and Control Households[a]

$$H_{t+1} = \beta[H_t^d - H_t] + \gamma[H_{t+1}^d - H_t^d] + \gamma\varepsilon\eta\,[H_{t+1}^d - H_t^d] + \beta\varepsilon\eta H_t^d + \phi H_t$$

	Pittsburgh			*Phoenix*		
	0–>1	*1–>2*	*Pooled Time Periods*	*0–>1*	*1–>2*	*Pooled Time Periods*
β	0.213 (7.24)	0.145 (5.80)	0.181 (9.56)	0.402 (9.62)	0.259 (7.09)	0.330 (11.87)
γ	0.466 (4.23)	0.444 (3.46)	0.376 (4.86)	0.462 (4.26)	0.534 (3.77)	0.512 (6.38)
ε	−0.278 (2.75)	−0.693 (2.68)	−0.359 (3.36)	−0.427 (2.49)	−0.374 (1.71)	−0.409 (3.65)
φ	1.022 (2.06)[b]	1.030 (3.12)[b]	1.032 (4.79)[b]	1.084 (4.95)[b]	1.053 (3.43)[b]	1.067 (5.94)[b]
R^2	.585	.702	.649	.535	.697	.613
Number of Observations						
Control	375	361	736	284	243	527
Experimental	424	407	831	302	265	567
Tests of Parameter Equality						
Control and Experimental Equality[c]		0.893	1.796		0.571	0.977
Time Period Equality[c]			2.031			2.399
β = γ[c]	5.240	5.493	6.434	0.297	3.770	6.214

Notes:
[a] t-statistics in parentheses.
[b] t-statistic calculated on null hypothesis that parameter equals one; i.e., that there were no changes in the relative prices of housing and other goods.
[c] F-statistics.
[d] t-statistics.

modest inflation in relative prices. The rate of inflation in market prices is consistently greater in Phoenix than in Pittsburgh.

The estimated price elasticity of demand is −0.64 in Pittsburgh and −0.45 in Phoenix. These are estimates of the long-run responsiveness of housing consumption to price changes, i.e., the consumption changes which would be observed after all households had fully adjusted to the changed housing prices. The short-run elasticities—those which would be observed after 1 year of altered prices—are considerably smaller. While a 10 percent reduction in housing prices would lead eventually to

a 6.4 percent increase in housing consumption in Pittsburgh, only a 1.2 percent increase is actually observed after the first year of the experiment. Similarly, in Phoenix an increase of only 1.6 percent in housing consumption (from a 10 percent rent reduction) is observed after the first year, even though a 4.5 percent increase is expected in the long run.

Table 4 presents the maximum-likelihood estimates of the expanded adjustment model, Equation (5), which distinguishes between initial levels of disequilibrium in housing consumption and changes in equilibrium demands. The estimates are replicated in two successive 1-year intervals for the same sample of households in each market.[18] Again, covariance tests indicate that the adjustment behavior of those households receiving experimental price reductions is no different from that of the control households. An F-test suggests that the estimated coefficients are identical for both time intervals. The results reported in Table 4 strongly suggest that there are significant differences in the rates of adjustment to current changes in equilibrium demands and to initial levels of disequilibrium. In Phoenix, three-fourths of a gap caused by any change in equilibrium demands is closed within 3 years; in Pittsburgh, it takes 6 years to effect this adjustment. As described below, there are statistical reasons, if not theoretical reasons, for preferring the estimates from the expanded models.

While the speed of adjustment is consistently greater in Phoenix than in Pittsburgh, the estimated price elasticity is quite similar for households in the two metropolitan areas. The point estimates of the long-run price elasticity of demand are between −0.35 and −0.41.

C. Statistical Complications

As with alternative estimation techniques for dynamic models, there are several potential statistical problems in the estimation of the parameters. With the technique of substitution, as opposed to the instrumental estimation here, this concern centers upon the estimated adjustment coefficient (which, after substitution, is the coefficient on the lagged dependent variable); in the presence of serial correlation of the errors (which might be induced by the substitution itself), the adjustment coefficient will be biased and inconsistent, and this will also lead to biases in the other coefficients. With this instrumental technique, the problems are somewhat different, since the adjustment coefficients are estimated directly from variations in the level of disequilibrium. Equations (4) and (5) are cross-sectionally estimated, and there is no reason to believe that errors in the adjustment equation are correlated with lagged consumption per se. However, the equilibrium demands are themselves estimated from the sample of households observed to be initially in equilibrium, and equilibrium levels of consumption are imputed to all households. Even if the parameters of the equilibrium demand relationships reported in Table 1 are unbiased and consistent, the estimated equilibrium demands will include a stochastic error. This error includes both a random component and a component representing unmeasured, household specific factors (e.g., taste differences). Of particular importance is the possibility of individual specific demand differences that persist over time. If time-invariant and unmeasured taste differences persist for individual households, this component of error will remain, even asymptotically, and the adjustment parameters will be estimated inconsistently. The asymptotic bias is a function of the variance in unmeasured taste differences relative to the variance in the systematic component of equilibrium demand. The results in Table 4 for the expanded adjustment model do provide some evidence about this, however. First, in Equation (5) the measure of changes in equilibrium demands eliminates any individual specific additive error component. The random (white noise) component of error in the estimate of the initial disequilibrium can, of course, bias the other parameter estimates; yet the estimates of γ are certainly less affected by these errors than the estimates of β. Second, because at $t = 0$ no household receives any subsidy, the actual estimation form for the adjustment models differs between time periods (see note 19). Thus, any errors in variables introduced by persistent unmeasured taste differences will have a differential effect on the parameter estimates across time periods. If such errors do have an important impact on the parameter estimates, one would expect the estimates to differ significantly between the two estimation periods.[19] Yet they do not. Thus, the indirect evidence indicates that systematic variations in tastes across individuals do not have an important effect upon the parameter estimates.

VI. CONCLUSIONS

For the simple models of stock adjustment, the 95 percent confidence interval for the price elasticity of housing demand is (−0.332 to −0.952) for Pittsburgh households and is (−0.197 to −0.709) for Phoenix households. For the expanded models the confidence intervals are (−0.222 to −0.538) and (−0.185 to −0.633) in Pittsburgh and Phoenix respectively. Although the long-run elasticity estimates obtained from the expanded models are smaller, the latter models suggest a more rapid response to price variation.

By way of comparison, the Muth (1971) analysis, which estimates the price elasticity from the production function for new housing, reports three estimates of the price elasticity with a 95 percent confidence interval of (−0.511 to −0.987). Polinsky and Ellwood (1979), using an identical

methodology, report two estimates, with a confidence interval of (−0.560 to −0.860). Again, these studies are for national samples of households and are confined to the purchasers of new single detached, FHA-insured housing.

Our analysis, based upon experimental manipulation, suggests that renters are somewhat less responsive to price variation and that responses do vary across housing markets.

This analysis also suggests, regardless of the "true" price and income elasticities of housing demand, that there are significant lags in adjustment to market variations; policies which subsidize housing consumption by reducing prices or increasing incomes may take some time to achieve results—if results are measured by increases in housing consumption. Finally, this analysis suggests that identical policies may have rather different effects across local markets.

The ultimate effect of any price or income subsidy policy also depends upon the elasticity of supply of housing services, and reliable estimates

Table 5. Percentage Change in Housing Consumption from a 10 Percent Reduction in Housing Prices as a Function of Demand and Supply Price Elasticities[a]

		Price Elasticity ε			
		Pittsburgh		*Phoenix*	
Adjustment Period/ Supply Elasticity		*Simple Adjustment ε = −409*	*Expanded Adjustment ε = −.642*	*Simple Adjustment ε = −.359*	*Expanded Adjustment ε = −.453*
A. After one year supply elasticity	0.2	0.75%	0.81%	0.89%	1.02%
	0.4	0.92	1.01	1.14	1.38
	0.6	0.99	1.10	1.26	1.55
	1.0	1.06	1.19	1.33	1.73
	∞	1.19	1.35	1.60	2.09
B. After five years supply elasticity	0.2	1.35%	1.13%	1.34%	1.30%
	0.4	2.03	1.57	2.00	1.92
	0.6	2.44	1.81	2.40	2.28
	1.0	2.91	2.05	2.86	2.69
	∞	4.11	2.58	4.01	3.69
C. After full adjustment supply elasticity	0.2	1.53%	1.28%	1.39%	1.34%
	0.4	2.46	1.89	2.12	2.02
	0.6	3.10	2.25	2.58	2.43
	1.0	3.91	2.64	3.12	2.90
	∞	6.42	3.59	4.53	4.09

Note:
[a] Calculations based upon estimated adjustment models of demand in Tables 3 and 4, assuming constant supply elasticities; see note 21.

of this parameter are even more problematic. de Leeuw and Ekanem (1971) and Struyk and Ozanne (1978) argue that the supply elasticity may be as low as 0.4; Smith (1976) argues that it may be larger by an order of magnitude. Table 5 presents some illustrative calculations of the effects of a given price subsidy policy upon housing consumption.[20] As the table indicates, in the long run, after suppliers and demanders have fully adjusted, such subsidies do result in significant (though inelastic) increases in housing consumption.[21] In the short run, however, the effects of price subsidy policies are more modest, even if supply is perfectly elastic. For example, in Pittsburgh only 64 to 72 percent of the eventual adjustment to a price reduction is actually observed after 5 years. In contrast, about 90 percent of the total adjustment in Phoenix is accomplished after 5 years. If the supply curve for housing is inelastic, clearly the short-run responses to price subsidies, as measured by housing consumption, are even smaller.

Similarly, responses to pure income subsidies would evolve slowly, even if subsidies were viewed by recipients as increases in long-run or "permanent" income. The income elasticity estimates reflect consumption responses in the long run—not those that would actually be observed during a short-run experimental period.

NOTES

1. For an extensive analysis of somewhat different models of price responsiveness using the same basic data, see Friedman and Weinberg (1978). Hanushek and Quigley (1981) provide a review of these and other investigations of data from the Housing Allowance Demand and Supply Experiments.

2. Particularly careful analytical reports on the effects of housing allowances may be found in Friedman and Weinberg (1978, 1979). See also Bradbury and Downs (1981).

3. This follows from a simple errors-in-variables argument. If housing consumption is a function of permanent income, the estimated income elasticity will be biased downward when estimated on the basis of nominal, or observed, income of individual households, even if the expected value of the transitory component is zero (see Hanushek and Jackson, 1977, chapter 10).

4. See Gillingham (1975) for a detailed discussion of the limitations of these data.

5. This conclusion is based upon a consideration of residential location and housing demand. Consider the regression of housing consumption upon income and the average price of housing in the local market, for a sample of individual households gathered across local markets. Standard residential location models (with some assumptions about the magnitude of demand parameters) imply that within any market (or urban area), higher-income households will locate further from the central workplace where housing prices are lower. In a sample of households drawn across local markets, average incomes and housing prices are positively correlated. Thus an increase in income increases the probability that a household will be located in a city of higher average income. Since the relative income of that household would be lower, it would locate closer to a city center in the city of higher average prices, where housing prices are yet higher. With price-inelastic demand, this overstates the change in housing consumption with respect to price. See Polinsky (1977).

6. Other papers (e.g., Quigley, 1976; King, 1975; Straszheim, 1975) also utilize intra-metropolitan housing prices, but they are of limited relevance to this study.

7. Analytically, this approach assumes that the production function for housing is constant elasticity of substitution (CES) in land and nonland inputs. The elasticity of substitution is estimated from the (logarithmic) regression of factor shares upon factor prices. With perfect competition, the price per unit of housing equals the equilibrium cost per unit, which can then be computed from the CES unit cost function.

8. The stock adjustment model, as conventionally applied to such behavior as investment or inventory accumulation, is often motivated by assumptions of either adjustment costs or dynamic expectations and may be a realistic description of both aggregate changes and individual firm responses. However, when adjustment costs have large fixed components, it is less reasonable to presume that individuals make a series of marginal adjustments in approaching equilibrium. Instead, those households who overcome the inertia generated by fixed costs might more realistically be assumed to adjust directly to their optimum consumption levels. In this case, the stock adjustment model is a characterization of aggregate market dynamics and the adjustment parameter is interpreted as the average propensity of households in disequilibrium to make adjustments, either by moving or by transforming their current dwelling units.

For most purposes, the focus upon the expected behavioral responses across the housing market provided by the stock adjustment formulation is adequate. This formulation does not, however, provide information about the distribution of outcomes across individual households. For this, a more detailed consideration of individual moving behavior is necessary (see Hanushek and Quigley, 1978; Weinberg et al., 1979).

9. Note that $[H^d_{t+1} - H_t] \equiv [H^d_t - H_t] + [H^d_{t+1} - H^d_t]$.

10. This would not be true if there were a significant housing price gradient in the cities. However, in estimating hedonic housing price models, Merrill (1977) tests for equality of coefficients between central city and suburban properties using a large sample of dwelling units in these two metropolitan areas. For Pittsburgh, it is not possible to reject the hypothesis of coefficient equality at the 5 percent level; for Phoenix, the hypothesis can be rejected, although the standard error of estimate only changes slightly with stratification. (See also note 14.) Independent analysis of the Pittsburgh area conducted for the NBER Urban Simulation Model by Gregory Ingram provided no evidence of a housing price gradient (reported in private correspondence).

11. All households who had moved within 12 months of initial observation were assumed to be in equilibrium, consistent with the assumed individual dynamics in note 8, above. Note that at baseline no households receive subsidies. Therefore, all recently moving households are used in this estimation regardless of subsequent treatment group assignment. There are a total of 404 such households in Pittsburgh and 630 in Phoenix. Some of these households subsequently received either constrained or unconstrained income subsidies and are not included subsequently in the estimation of the dynamic models. Other households from the control group or "percent of rent" subsidy group that had not recently moved are included in the adjustment estimation but not in the equilibrium demand estimation.

Implicitly, Muth (1971) and Polinsky and Ellwood (1979) make the same assumptions about equilibrium demands since their estimates utilize data on newly purchased homes and the behavior of recent movers.

12. Identification of equilibrium behavior on the basis of past moving behavior does introduce the potential for bias through "selectivity" effects. If some households intrinsically value housing more (in ways that are not captured by the parameterization of the equilibrium demand relationships), we would expect them to adjust more rapidly to disequilibrium in demand (holding constant adjustment costs). This would imply that the sample of recent movers would disproportionately sample "high demanders" for housing.

and the estimated income elasticities and other parameters would tend to be biased upward. While estimation of the possible "selectivity bias" might be possible through incorporation of moving probabilities, it is difficult to do this in a completely satisfactory manner.

13. Data were actually gathered at four different times by observing household information 6 months after enrollment (that is, at $t = \frac{1}{2}$). The empirical analysis reported below was also conducted for the two 6-month periods $0 \rightarrow \frac{1}{2}$, $\frac{1}{2} \rightarrow 1$, and standard covariance tests indicated no behavioral differences across these time periods. The results here are reported for the two 1-year periods; the results from the analysis of the shorter time intervals are available upon request.

14. There is some empirical evidence on the relative magnitude of the reductions in gross rent attributable to long-term occupancy. Kain and Quigley (1975) report small but statistically significant discounts in the market rents of otherwise comparable dwelling units attributable to longer occupancy (about 0.5 percent for each year of residence). Schafer (1979) finds considerably larger discounts to long-term tenure in the Boston housing market based upon the 1970 Public Use sample.

Tenure discounts were estimated in the Pittsburgh and Phoenix housing markets in an analysis of hedonic prices conducted by Merrill (1977). In that study, log rent is regressed upon a series of structure and quality measures of individual dwelling units and the length of tenure of the occupying household. The regression coefficients, based on a sample of 1509 dwelling units in Pittsburgh and 1601 dwelling units in Phoenix, imply significant price discounts for long-term residents. In Pittsburgh, the results indicate discounts of 2 percent for households with 1–5 years of occupancy, increasing to 10 percent for households with more than 10 years of occupancy. In Phoenix, the tenure discounts range from 4.4 percent for households with 1–5 years of occupancy to 19 percent for households with more than 10 years of occupancy. These coefficients permit housing consumption expenditures to be normalized to the prices facing new occupants.

15. Households in the subsidy group received this percentage rent rebate regardless of their subsequent housing market behavior. Further, the experimental payments were actually received for a full year after the period examined here, so it is reasonable to presume that the subsidy was not largely discounted because of the fixed duration of the experiment.

In addition, about 1000 households in Pittsburgh and Phoenix received various other kinds of transfer payments under experimental housing allowance formulas which were based upon income, family size, and certain restrictions on housing consumption. For details, see Bradbury and Downs (1981). These households are not analyzed here.

Finally, since the experimental group is so small relative to the housing market as a whole, there is no perceptible supply response, and the price elasticity is identified.

16. For Phoenix, the hypothesis of coefficient equality across time periods is rejected in the simpler model at the 5 percent level. However, in the more complex model (Table 4), time period equality of coefficients is not rejected.

17. Since $\eta = 0$ for the control households, the relevant test is for equality of α and ϕ values across samples in each time period.

18. In estimating Equation (5), it must be recognized that $\eta = 0$ for all households at the beginning of the experiment. Thus, for the first interval ($0 \rightarrow 1$) the estimated model is

$$H_1 = \beta[H_0^d - H_0] + \gamma[H_1^d - H_0^d] + \gamma\epsilon\eta H_1^d + \phi H_u$$

and for the second interval ($1 \rightarrow 2$), the estimated model is

$$H_2 = \beta[H_1^d - H_1] + \gamma[H_2^d - H_1^d] + \gamma\epsilon\eta[H_2^d - H_1^d] + \beta\epsilon\eta H_1^d + \phi H_u.$$

As noted below, this difference in estimation form provides additional information about the statistical properties of the model.

19. The exact expressions for relative bias are not easily derived because of the large number of parameters and the nonlinearities of the model. The measurement errors may offer an additional explanation for the consistently smaller estimates of β compared with γ.

20. Presumably, the rest of society is willing to provide this "inefficient" subsidy only because it has a direct interest in the housing consumption of low-income households.

21. The table illustrates the responsiveness of housing consumption to price subsidies conditional upon alternative supply elasticities. These are obtained by substitution using the uncompensated demand curve. Entries in the table are $\delta\bar{\epsilon}_\tau/(\delta - \bar{\epsilon}_\tau)$, where δ is the supply elasticity and $\bar{\epsilon}_\tau$ is the responsiveness of demand to price change after period τ. (For example, in the simple model, after one period, $\bar{\epsilon}_1 = \alpha\epsilon$ and after full adjustment $\bar{\epsilon}_\infty = \epsilon$.)

REFERENCES

Aaron, H. (1972). *Shelter and Subsidies.* Washington, D.C.: Brookings Institution.

Bradbury, K., and A. Downs (eds.) (1981). *Do Housing Allowances Work?* Washington, D.C.: Brookings Institution.

Carliner, G. (1973). "Income Elasticity of Housing Demand." *Review of Economics and Statistics* (November):528–531.

de Leeuw, F. (1971). "The Demand for Housing: A Review of the Cross-Section Evidence." *Review of Economics and Statistics* (February):1–10.

de Leeuw, F., and N. F. Ekanem (1971). "The Supply of Rental Housing." *American Economic Review* (December):806–817.

Fenton, C. G. (1974). "The Permanent Income Hypothesis: Source of Income and the Demand for Rental Housing." Harvard–MIT Joint Center for Urban Studies, Cambridge, Mass.

Friedman, J., and D. H. Weinberg (1978). *Draft Report on the Demand for Rental Housing: Evidence from a Percent of Rent Housing Allowance.* Cambridge, Mass.: Abt Associates.

——— (1979). *Draft Report on Housing Consumption under a Constrained Income Transfer: Evidence from a Housing Gap Housing Allowance.* Cambridge, Mass.: Abt Associates.

Gillingham, R. (1975). "Place-to-Place Rent Comparisons." *Annals of Economic and Social Measurement* (Winter):153–173.

Hanushek, E. A. (1981). "Alternative Models of Earnings Determination and Labor Market Structure." *Journal of Human Resources* (Spring):238–259.

Hanushek, E. A., and J. E. Jackson (1977). *Statistical Methods for Social Scientists.* New York: Academic Press.

Hanushek, E. A., and J. M. Quigley (1978). "An Explicit Model of Intra Metropolitan Mobility." *Land Economics* (November):411–428.

——— (1979). "The Dynamics of the Housing Market: A Stock Adjustment Model of Housing Consumption." *Journal of Urban Economics* (January):90–111.

——— (1981). "Complex Public Subsidies and Complex Household Behavior: Consumption Aspects of Housing Allowances." In K. Bradbury and A. Downs (eds.), *Do Housing Allowances Work?* Washington, D.C.: The Brookings Institution.

Kain, J. F., and J. M. Quigley (1975). *Housing Markets and Racial Discrimination.* New York: National Bureau of Economic Research.

King, A. T. (1975). "The Demand for Housing: Integrating the Roles of Journey-to-Work, Neighborhood Quality, and Prices." In N. E. Terleckyz (ed.), *Household Production and Consumption.* New York: NBER.

Mayo, S. K. (1978). "Theory and Estimation in the Economics of Housing Demand."

Paper prepared for the North American Meetings of the Econometric Society, Chicago, Illinois, August.

Merrill, S. R. (1977). *Draft Report on Hedonic Indices as a Measure of Housing Quality*. Cambridge, Mass.: Abt Associates.

Murray, M. P. (1975). "The Distribution of Tenant Benefits in Public Housing." *Econometrica* (July):771–788.

Muth, R. F. (1971). "The Derived Demand for Urban Residential Land." *Urban Studies* (October):243–254.

——— (1960). "The Demand for Non-Farm Housing." In A. C. Harberger (ed.). *The Demand for Durable Goods*. Chicago: University of Chicago Press.

Polinsky, A. M. (1977). "The Demand for Housing: A Study in Specification and Grouping." *Econometrica* (March):447–461.

Polinsky, A. M., and D. T. Ellwood (1979). "An Empirical Reconciliation of Micro and Grouped Estimates of the Demand for Housing." *Review of Economics and Statistics* (May):199–205.

Quigley, J. M. (1976). "Housing Demand in the Short Run: An Analysis of Polytomous Choice." *Explorations in Economic Research* (Winter):76–102.

Schafer, R. (1979). "Racial Discrimination in the Boston Housing Market." *Journal of Urban Economics* (April):176–196.

Smith, B. A. (1976). "The Supply of Urban Housing." *Quarterly Journal of Economics* (August):389–405.

Straszheim, M. (1975). *An Econometric Analysis of the Urban Housing Market*. New York: NBER.

Struyk, R. J., and L. Ozanne (1978). "The Price Elasticity of Supply of Housing Services." In L. S. Bourne and J. R. Hitchcock (eds.). *Urban Housing Markets: Recent Directions in Research and Policy*. Toronto: University of Toronto Press.

Sweeney, J. L. (1974). "Housing Unit Maintenance and the Mode of Tenure." *Journal of Economic Theory* 8(2):111–138.

Weinberg, D. H., J. Friedman, and S. K. Mayo (1979). "A Disequilibrium Model of Housing Search and Residential Mobility." Paper prepared for the Conference on the Housing Choices of Low-Income Families, Washington, D.C., March.