The Dynamics of the Housing Market: A Stock Adjustment Model of Housing Consumption

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The importance of transactions costs and conversion costs in the market for residential housing suggests that the observed housing consumption of an individual household will generally differ from its "equilibrium" level of demand (i.e., the housing consumption freely chosen in a frictionless world, given prices, incomes, and tastes). This paper develops an explicit model of this process and provides estimates of alternative stock adjustment models for two samples of renter households. Desired or "equilibrium" housing demand models are estimated from samples of recent mover households; these demand parameters are then used to estimate the rate of adjustment to household equilibrium. The empirical analysis is replicated for two samples and for two time intervals. The results strongly indicate that there are significant lags in adjustment, even for low income renter households. Failure to account for this dynamic structure may give misleading conclusions about the operation of the housing market in the short run and the effects of public policies.

1. INTRODUCTION

One of the distinguishing features of housing as an economic commodity is the substantial transactions cost associated with changing the set of housing services consumed. Typically, the act of choosing a different dwelling unit is associated with significant search costs, with the costs of moving household possessions, and often with nontrivial contracting costs, including brokers' fees, security payments, and the like. These transaction costs would be of little consequence in understanding consumer behavior if dwelling units were relatively malleable and if the housing services emitted by any dwelling unit could be modified inexpensively. However, the scope for modification of existing dwelling units in response to changes

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in the housing demands of their occupants is demonstrably limited, and any such modification is usually quite costly.

These factors imply that households' consumption of housing in any period may deviate significantly from their "equilibrium" levels of consumption (i.e., the amounts of housing freely chosen in a frictionless world, given household incomes, preferences, and relative prices). This paper focuses on the adjustment process by which households modify their observed consumption of housing services over time to close the gap between their actual and preferred consumption levels.

The empirical analysis discussed below is based upon reinterview data gathered for renter households as a part of the Housing Allowance Demand Experiment (HADE) currently underway in the Phoenix and Pittsburgh metropolitan areas. Specifically, the conceptual model is tested using households in the HADE "control groups" (i.e., households from which data are gathered, but which are otherwise unaffected by the experiments).

While the main purpose of the housing allowance experiment is to provide information about the responses of low income households to direct housing subsidies, the unique data gathered in the experiment can support much broader analyses. In particular, the repeated observations describing individual households and their housing consumption within identified housing markets permit for the first time, serious analysis of the short-run dynamics of housing adjustment. The usefulness of these data is enhanced by their availability in two rather different housing markets, thus making possible more extensive tests of housing market dynamics. Nevertheless, it should be noted at the outset that the empirical analysis which is used here to evaluate the conceptual model is limited (by the design of the experiment) to renters in lower income groups.

2. CONCEPTUAL FRAMEWORK

We begin by assuming that households of given sociodemographic characteristics A derive utility from their consumption of "housing services" H and other goods X:

$$U_A(H, X) = V(A, H, X), \tag{1}$$

where $V(\cdot)$ is an indicator of the utility derived by households with characteristics A from their consumption of H and X. Maximization of utility subject to the household budget constraint:

$$Y = P_H H + X, \tag{2}$$

(where Y is household income, P_H is the price of housing, and the price of other goods is the numeraire), yields a conventional demand curve for housing services

$$H = f(A, Y, P_H). \tag{3}$$

Equation (3) indicates the utility maximizing flow of housing services freely chosen. We denote this "desired level" of housing consumption at time t by $H_t{}^d$ and note that at time τ the desired consumption level $H_\tau{}^d$ may differ due to changes in household income Y, demographic characteristics A, or changes in relative prices, P_H.

Let H_t represent the actual housing consumption of the household observed at time t. As noted previously, if mobility were costless or if housing capital could be modified cheaply at all residential sites, each household would continuously adjust its location or the characteristics of its dwelling unit so that $H_t = H_t{}^d$.

If $H_t < H_{t+1}{}^d (> H_{t+1}{}^d)$, households will have an incentive to modify their housing consumption by purchasing more (less) housing services. However, due to the monetary and psychic costs of adjustment, equilibrium and observed housing consumption will generally differ. The strength of the economic forces causing households to modify their consumption of housing services is measured by the size of the "gap" between desired housing consumption and its initial level, $[H_{t+1}{}^d - H_t]$. If we consider a group of households with similar moving costs, we should expect a monotonic relationship between the size of the disequilibrium gap and the incentive for its elimination.

Households may eliminate the gap between actual and desired levels of housing consumption either by changing the characteristics of their current dwelling units or by moving. Since the scope for modification of existing dwelling units in response to changing housing demands is limited, particularly for renter households, it is reasonable to expect that the "gap" is eliminated largely by intra-metropolitan residential mobility.

If we assume that, on average, households adjust to their equilibrium positions by closing the gap between actual and desired housing at a constant rate, the relationship between consumption levels over time is

$$H_{t+1} = \alpha[H_{t+1}{}^d - H_t] + \phi H_t \tag{4}$$

where α is the rate of adjustment to equilibrium and ϕ is one plus the relative rate of housing price inflation during the interval between t and $t + 1$.[1] This formulation need not imply that individual households

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[1] By analogy to models of earnings and human capital investment, Eq. (4) indicates that observed housing consumption in any period depends upon the entire history of desired housing consumption, i.e.,

$$H_t = \sum_{i=1}^{t} \alpha(\phi - \alpha)^{t-i} H_i{}^d + (\phi - \alpha)^t H_0. \tag{N-1}$$

More generally, if the inflation rate differs between periods, the expression becomes

$$H_t = \alpha H_t{}^d + \alpha \sum_{i=1}^{t-1} H_i{}^d \prod_{j=i+1}^{t} (\phi_j - \alpha) + H_0 \prod_{j=1}^{t} (\phi_j - \alpha). \tag{N-2}$$

eliminate $100\alpha\%$ of the gap between actual and desired housing during a given period. It is more reasonable to presume that those households who choose to move eliminate completely the gap between their desired and actual levels of housing consumption. Thus, the coefficient of adjustment measures the average propensity to respond (either by moving or by transforming the bundle of housing services at the same location) in response to disequilibrium in housing consumption.

The gap between the desired consumption level at $t + 1$ and the observed consumption level at t can be decomposed into two components:

$[H_t{}^d - H_t]$, which measures the gap between initial consumption and the desired consumption level, and

$[H_{t+1}{}^d - H_t{}^d]$, the change in the equilibrium level of housing consumption during the period.

A more general model of the stock adjustment process would distinguish between these components of change and investigate differential behavioral responses. In a more general formulation,

$$H_{t+1} = \beta[H_t{}^d - H_t] + \gamma[H_{t+1}{}^d - H_t{}^d] + \phi H_t, \qquad (5)$$

β measures the average speed of adjustment of housing consumption from the initial disequilibrium position, and γ measures the speed of adjustment to current-period changes in equilibrium levels of housing consumption. We may expect that, on average, households adjust more rapidly to changes in their equilibrium position than to the magnitude of their initial disequilibrium, i.e., $\gamma > \beta$. This would imply that an exogenous change in the factors affecting housing demand (say, a change in income or family size) would cause households to adjust their housing consumption more rapidly in the current period and to adjust less rapidly in subsequent periods to a new equilibrium position. Interpreted in terms of mobility behavior, this formulation hypothesizes that households are more likely to move in response to an exogenous change in housing demand in the period in which it occurs; in subsequent periods they are successively less likely to move.

In addition, there is some reason to expect a "rachet effect" in housing consumption, leading to asymmetry in the adjustment process. We anticipate that households whose current housing consumption is less than their desired level will adjust to equilibrium more rapidly than those

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If the time dependency of desired housing consumption $H^d(t)$ were known with certainty, Eq. (4) could be reformulated to indicate the optimal pattern of observable lifetime housing consumption, given a time pattern of transaction costs. However, we view the uncertainty about households' future housing demands as being the essence of this problem.

whose current consumption is greater than their desired level. Similar reasoning leads to the expectation that those whose desired level of housing services increases will adjust towards equilibrium faster than those whose desired level decreases. Thus, a more general model, based on Eq. (4) is:

$$H_{t+1} = \alpha^+ \delta_1 [H_{t+1}{}^d - H_t] + \alpha^- \delta_2 [H_{t+1}{}^d - H_t] + \phi H_t. \qquad (6)$$

where

$$\delta_1 = 1, \quad \delta_2 = 0 \quad \text{if} \quad H_{t+1}{}^d > H_t$$

$$\delta_1 = 0, \quad \delta_2 = -1 \quad \text{if} \quad H_{t+1}{}^d < H_t$$

with the expectation that $\alpha^+ > \alpha^-$.

A straightforward generalization of this asymmetry in adjustment based upon Eq. (5), is:

$$\begin{aligned}
H_{t+1} = \beta^+ \delta_1 [H_t{}^d - H_t] &+ \beta^- \delta_2 [H_t{}^d - H_t] \\
&+ \gamma^+ \delta_3 [H_{t+1}{}^d - H_t{}^d] + \gamma^- \delta_4 [H_{t+1}{}^d - H_t{}^d] + \phi H_t \quad (7)
\end{aligned}$$

where

$$\delta_1 = 1, \quad \delta_2 = 0 \quad \text{if} \quad H_t{}^d > H_t; \quad \delta_3 = 1; \quad \delta_4 = 0 \quad \text{if} \quad H_{t+1}{}^d > H_t{}^d;$$

$$\delta_1 = 0, \quad \delta_2 = -1 \quad \text{if} \quad H_t{}^d < H_t; \quad \delta_3 = 0; \quad \delta_4 = -1 \quad \text{if} \quad H_{t+1}{}^d < H_t{}^d,$$

with the expectations that $\gamma^{+,-} > \beta^{+,-}$; $\beta^+ > \beta^-$, $\gamma^+ > \gamma^-$.

Unfortunately, Eqs. (4) through (7) cannot be estimated directly since they include a term for equilibrium demand which is unobserved. The following section discusses the derivation of this variable.

3. EQUILIBRIUM DEMAND

A single cross section will generally include some individuals who have not yet adjusted their housing consumption to its equilibrium position. Therefore, without some information about the dynamic adjustment process, the estimation of housing demand models from cross-sectional data could give misleading impressions about the true demands for housing, at least, if the adjustments follow the more complex patterns sketched above. The importance of dynamic elements can be inferred, in part, from the mobility level of households. Figure 1 displays the length of tenure at the current address of urban households in the U. S. in 1973. For all households, only 20% have made an adjustment in their housing consumption by moving within the last year. While the mobility level of renters is substantial, it still seems reasonable to infer that a large fraction of urban renters have undergone changes in circumstances which would vary their desired housing consumption but which have not yet been reflected in their housing consumption at a given point in time.

Past analyses of housing demand have provided a body of somewhat conflicting results about the values of key parameters. For the most part,
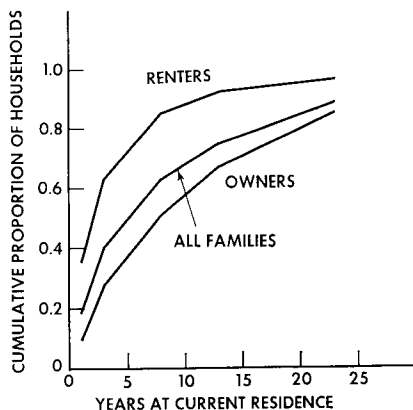
FIG. 1. Distributions of owner and renter households by years at current residence. Source: U. S. Department of Housing and Urban Development, "Annual Housing Survey, 1973" Government Printing Office, Washington, D. C. (1975).

the results seem quite dependent upon the particular sample and the level of aggregation employed.

Research based upon aggregate time series or cross-sectional data using entire cities as units of observation has established the sensitivity of housing demand to its relative price and to the average incomes of residents (see Reid [12] and Muth [9]). Considerable research has focused on the measurement and interpretation of the average income variable used in aggregate studies, and there seems to be a consensus on two points:

(1) that the average income variables are to be interpreted as proxies for long run or "permanent" income; and

(2) that the elasticity of housing demand with respect to permanent income is quite large and may exceed 1.0 (see deLeeuw [3]).

More recently, there have been several studies estimating the demand for residential housing based upon micro data on individual households and their dwelling units (see Straszheim [14], Carliner [2], and Kain and Quigley [7]). These studies suggest:

(1) that the elasticity of housing demand may be considerably lower with respect to annual household income and may be on the order of 0.3 to 0.6; and

(2) that both annual income and permanent income, (the latter measured somewhat crudely) are important in explaining the pattern of housing demand.[2]

[2] Carliner's analysis [2], as well as the work by Aaron [1], measures permanent income by a distributed lag of annual income; Kain and Quigley [7] use average incomes stratified by race and years of education as a measure of permanent income.

In addition, these more recent analyses suggest that other factors besides price and income, however measured, are important determinants of the demand for housing services. For example, these analyses indicate *ceteris paribus* that larger households demand more housing services, that black households consume substantially less housing services than "otherwise comparable" white households, and that housing demand varies systematically with age and education (if only because these latter variables are proxies for long-run income).

deLeeuw [3], in his review of previous demand estimates, attempts to reconcile the conflicting evidence reported in aggregate studies through careful consideration of the sampling schemes and the measurement of housing consumption and exogenous variables. More recently, Polinsky [11] has provided a theoretical discussion of model specification and aggregation which could reconcile results reported in aggregate and micro analyses of housing demand. This analysis builds upon the observation that, if a housing price gradient exists and is ignored in an econometric formulation, it will have differing effects upon the estimated income (and price) elasticities when different units of observation and sampling schemes are used.

Consideration of the dynamics of housing consumption and the impact of disequilibrium observations on the parameter estimates provides an additional reason for differences in parameter estimates. The existence of disequilibrium in the housing market will have a larger impact on estimation using individual households as units of observation; using aggregate data, the disequilibrium levels of individual households will tend to "net out." Thus, using micro data, the parameters estimated from a single cross-section will represent short run elasticities, presumably lower than the comparable aggregate estimates which represent long run behavior. However, the estimates based on aggregate data will be biased: if the aggregate level of disequilibrium in the market does not average out; or even if the average disequilibrium is zero, as long as the adjustment process follows either of the more complex patterns, Eqs. 6 or 7, described above.

The adjustment model itself is framed in terms of the (unobserved) "equilibrium" demands. A common technique for estimating such adjustment models (particularly in macro economic applications, e.g., investment functions) is to solve the adjustment equation in terms of observed variables, i.e., to substitute for the desired, or equilibrium, demands. For several reasons, we do not do this, but instead estimate the equilibrium demands directly for use in the adjustment models. First, this direct formulation allows analysis of whether changes in household circumstances operate through changing equilibrium demands, changing the adjustment pattern, or both. Second, by estimating the equilibrium

demands directly and using these in the adjustment models, it is possible to test for a variety of adjustment patterns, such as the extended models (Eqs. 5, 6, and 7) which allow for different adjustment speeds with particular components of disequilibrium. Third, the longitudinal information available for this particular analysis is relatively short (two 6 month periods); substitution to eliminate the equilibrium demands requires very strong assumptions about the time paths of adjustment, and the data are too thin to obtain very reliable estimates of this long run adjustment path. (Contrast this to the estimation in macro models (e.g., Muth [10], Lee [8]) where relatively long time series allow many more degrees of freedom in estimation of the adjustment path). Finally, the equilibrium demand models are of independent interest.

Distinguishing that group of households consuming their equilibrium levels of housing service is problematical, and a review of past research provides little guidance. Muth's original study of housing demand [10], based upon time series data (1915–1941) for the nation as a whole, suggests an aggregate adjustment coefficient of 0.3. Although it is outside the spirit of his model, he appears at one point to interpret his aggregate results as if each individual household removed 30% of the discrepancy between actual and desired housing consumption in each year. deLeeuw and Ekanem's [4] simulation model also specifies a stock adjustment model for an entire housing market, but they do not evaluate their simulations in terms of individual behavior. The dynamic models above suggest that inertia and significant transactions costs prevent individual households, in general, from consuming that level of housing services which would be optimal on the basis of income, housing prices, and other demographic characteristics.[3] However, there seems little reason to presume that those households which are currently making relocation decisions (and are observed to have overcome the inertia) would *not* choose to consume their most preferred levels of housing services. Our characterization of this dynamic process, at the micro economic level, thus assumes that moving households do choose equilibrium consumption levels; having chosen their optimal levels of housing consumption, changes in family circumstances cause households to drift from equi-

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[3] If transactions costs were known, this information might be used to reformulate the model and to define the sample of individuals who would be expected to be near equilibrium. Unfortunately, there is very little empirical evidence about the monetary and utility costs of intrametropolitan moves. There is crude evidence about out-of-pocket costs for owner occupants (see deLeeuw and Ekanem [5], and Shelton [13]). These estimates, suggesting that transactions costs may be on the order of 10 to 20% of annual housing expenses, certainly overstate the monetary costs for renters since they include legal and brokerage fees. It should be noted, however, that in addition to the out-of-pocket costs of moving, there are substantial psychic costs since social networks, school attendance, and other habits of urban life are likely to be altered by relocation.

librium. The analysis thus suggests that equilibrium housing demands are freely expressed by "recent movers" in any housing market.

Estimation of the equilibrium demands for housing is based upon observations of individual households in two metropolitan areas, Pittsburgh and Phoenix, in 1973. In each metropolitan area, a stratified random sample of households was drawn; information about the initial (indicated subsequently by $t = 0$) housing consumption, income, and sociodemographic composition of each household was gathered. Certain retrospective data were also gathered for each household at $t = 0$. Subsequently, households were assigned to a "treatment" or a "control" group and similar information was gathered after a 6 month interval ($t = 1$) and again after a second 6 month interval ($t = 2$).

The equilibrium demand models reported below are estimated using the sample of "recent movers" households in each city, i.e., those who moved into their $t = 0$ dwelling units within the previous 12 months.[4]

We hypothesize that the equilibrium housing demands for this group of recent movers is a function of annual income, wealth, household size, age, years of education, and varies by race. Appendix Tables A1 and A2 compare the average of these sociodemographic characteristics for the group of recent movers (collected in 1973-74) with published census information (for 1969) for the two metropolitan areas. Also included are the average sociodemographic characteristics of the control households, which are used below to test the stock adjustment models. The comparisons reveal that the sampled households are slightly larger, are headed by older individuals with slightly less education, and are of about the same racial composition as the average households in each housing market.

However, it should be noted that the sampled households are, by design, not representative of the populations in the metropolitan areas. In particular, they have substantially lower incomes than the representative household. Therefore, some caution must be used in extrapolating the results to the entire population, at least if one believes that the parameters of interest are different, for some reason, for low income households.

The equilibrium demand equations were estimated in several alternatives to investigate the specification of age or "life cycle" effects. Demand models were estimated with a linear and a quadratic age term (see Appendix Table A3). In addition, each sample was stratified into two age groups (less than 45 years, and 45 years and older) to test for complete

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[4] For the demand estimation, which is carried out using the initial data on households, it is irrelevant which experimental treatment group the household is ultimately assigned to. Therefore, the demand estimation uses all sample households which satisfy the recent move condition, irrespective of subsequent experimental treatment.

TABLE 1

Housing Demand Equations for Recent Mover Households
Stratified by Age

Variable	Pittsburgh		Phoenix	
	Young	Old[a]	Young	Old[a]
Income (thousands)	4.020	4.920	6.290	5.660
	(3.19)	(2.11)	(7.74)	(3.14)
Assets (thousands)	−1.310	1.118	1.230	1.230
	(0.98)	(1.58)	(0.93)	(1.32)
Education (years)	4.950	1.318	3.647	0.600
	(5.06)	(0.93)	(4.91)	(0.49)
Household size	3.511	8.479	1.144	3.795
	(1.27)	(3.65)	(0.94)	(1.49)
Black	−15.383	−13.159	−25.541	−23.443
	(3.61)	(1.56)	(4.02)	(1.56)
Other nonwhite	−14.935	−3.761	−16.370	−4.466
	(0.80)	(0.11)	(4.20)	(0.41)
Age	1.403	0.450	1.312	−0.586
	(4.62)	(1.09)	(4.90)	(1.47)
Refrigerator	22.267	−13.272	−6.470	2.295
	(2.89)	(0.87)	(1.40)	(0.23)
Stove	1.074	25.063	22.926	−6.868
	(0.16)	(1.80)	(4.79)	(0.57)
Air conditioner	—	—	15.488	27.616
			(2.05)	(1.76)
Constant	1.283	32.408	7.418	104.907
R^2	0.318	0.359	0.315	0.247
df	313	91	502	128
Estimated income elasticity (at point of means)	0.144	0.168	0.238	0.185
Estimated income elasticity (at SMSA medians)	0.515	0.630	0.590	0.531

[a] Head of household aged 45 or more.

interaction of the age variable. The relevant F-test indicates that the sample should be stratified, and these models are presented in Table 1.[5] Including the age stratification, the demand estimates reported in Table 1 explain 38% of the variation in contract rents in Phoenix and 33% in Pittsburgh.

The dependent variable in each of the regressions presented is monthly contract rent, which differs from the index of monthly housing services

[5] For the Pittsburgh sample, the reduction in the residual sum of squares, when compared with the pooled model including age and age-squared is significant at the 0.05 level ($F = 2.24$). For Phoenix, the corresponding F ratio ($F = 1.90$) is significant at the 0.10 level.

(or gross rent) by the terms of individual landlord-tenant agreements. To adjust for this, the demand equations include dummy variables if the landlord provides major appliances. The individual estimates of the appliance premiums are imprecise; however, F-tests for the sets of coefficients indicate that they are jointly important.[6]

The regression estimates presented in Table 1 and in the Appendix provide considerable support for the qualitative results of previous analyses of the demand for housing based upon micro data. At the point of sample means, the income coefficient suggests an elasticity of housing demand with respect to annual income of about 0.15 in Pittsburgh and about 0.23 in Phoenix. The low average income elasticity computed from the linear model reflects the over sampling of low income households. At the SMSA median income and rent levels, the elasticity of housing demand with respect to annual income is estimated to be 0.52 to 0.63 in Pittsburgh and 0.53 to 0.59 in Phoenix.

The models also include the education level of the household head which is, in part, a proxy for permanent income effects. The independent effects of education level indicate that the elasticity with respect to current income understates the elasticity with respect to permanent income.[7]

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[6] For the four columns of Table 1, the F-ratios are 2.18, 0.56, 4.30, and 3.51, respectively.

[7] It is possible to approximate the "income elasticity" associated with the education term, at least crudely, 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 (Tables 1, A3) are

$$H^d = A_0 + A_1(Y_p + Y_t) + A_2 ED + \cdots, \tag{N-3}$$

where ED is years of schooling. Then the elasticity of demand with respect to Y_p,

$$\epsilon_{Y_p} = \frac{\partial H^d}{\partial Y_p} \cdot \frac{Y_p}{H^d} = \left[A_1 + A_2 \cdot \frac{1}{\partial Y_p / \partial ED} \right] \frac{Y_p}{H^d}. \tag{N-4}$$

Separate estimates of the earnings model.

$$\log Y_p = b_0 + b_1 ED + b_2 EX + b_3 EX^2, \tag{N-5}$$

(where EX is experience) were made for male workers in the Pittsburgh and Phoenix SMSA's from the 1970 Public Use Sample (see Hanushek [6]). For Phoenix b_1 is estimated to be 0.060, and for Pittsburgh b_1 is estimated to be 0.085. Substitution of the values reported in Tables A1 and A2 into (N–4) yields estimates of elasticities of housing demand with respect to permanent income (ϵ_{Y_p}) of:

	ϵ_{Y_p} estimated at	
	Sample means	SMSA medians
Phoenix	0.55	1.02
Pittsburgh	0.51	1.13

TABLE 2

Basic Stock Adjustment Model

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

	Phoenix			Pittsburgh		
	$0 \to 1$	$1 \to 2$	Pooled	$0 \to 1$	$1 \to 2$	Pooled
α	0.278	0.265	0.270	0.124	0.159	0.143
	(6.10)	(6.04)	(8.53)	(4.22)	(5.19)	(6.75)
ϕ^a	1.022	1.046	1.004	1.016	1.001	1.008
	(1.47)	(3.12)	(0.35)	(1.90)	(0.16)	(1.35)
R^2	0.630	0.694	0.661	0.762	0.746	0.753
SEE	31.66	29.08	30.44	19.81	21.58	20.71
df	305	278	587	385	382	769
Stratification test:						
(F-ratio)			0.73			0.97

Note: t-statistics in parentheses.

[a] t-statistics refer to the null hypothesis that $\phi = 1.0$ (i.e., that the rate of housing price increase equals the rate of overall price inflation).

The regression also indicates that black households in Pittsburgh (Phoenix) spend 12% (13%) less on housing than otherwise comparable whites. There is no indication that the housing market behavior of those few other non-white households in Pittsburgh differs from that of whites. But in Phoenix, where other non-whites (Mexican-Americans) comprise 28% of the sample, the results suggest that they spend 13% less on housing services than comparable white households. Larger households consistently demand more housing services.

One novelty of these demand equations is the inclusion of household

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While these estimates are somewhat crude, they do suggest that a substantial part of the differences in income elasticities reported in micro and aggregate studies of housing demand may be reconciled by considering the effect of education on long run income.

Secondly, if we consider the effect of estimating the demand models for all individuals in these two samples and not just recent movers (i.e., including households whose observed consumption is not in equilibrium), we find substantially lower estimates of elasticites with respect to current income (9% lower in Phoenix, and 43% lower in Pittsburgh). The difference between the two cities is consistent with the higher mobility rate of Phoenix (which would suggest the amount of disequilibrium across individuals would be less there).

Finally, the bias noted by Polinsky [11], arising from ignoring a price gradient term in the demand models, is probably unimportant for these two particular cities. Both SMSA's have very dispersed employment sites and residential patterns (Pittsburgh has the flattest density gradient of 46 cities analyzed by Muth [9]) which suggest small price gradients. In addition, direct investigation of price gradients for Pittsburgh conducted in conjunction with NBER housing model (reported by Ingram in private correspondence) was fruitless.

assets as a crude proxy for household wealth. The inclusion of the asset measure seems to have little effect upon housing consumption, at least the housing consumption of low income renters.

4. TESTING THE STOCK ADJUSTMENT MODEL

Estimates of the equilibrium housing demand function permit a direct investigation of the stock adjustment model. In this section, these adjustment models are estimated separately for the two samples of control households in Phoenix and Pittsburgh.

For each sample household, its actual housing consumption at three points in time (H_0, H_1, H_2) is observed. Estimates of its equilibrium housing demand (H_0^d, H_1^d, H_2^d) are obtained from its income and sociodemographic composition at times 0, 1, and 2 by using the demand functions reported in Table 1.

Table 2 presents estimates of the basic stock adjustment model (Eq. 4) for both groups estimated for two intervals; Table 3 presents estimates of the more general adjustment model which distinguishes between the initial level of disequilibrium and changes in equilibrium demands.

The estimated adjustment coefficient for Pittsburgh households is

TABLE 3

Expanded Stock Adjustment Models

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

	Phoenix			Pittsburgh		
	$0 \to 1$	$1 \to 2$	Pooled	$0 \to 1$	$1 \to 2$	Pooled
β	0.272	0.266	0.269	0.122	0.157	0.141
	(5.91)	(6.04)	(8.44)	(4.16)	(2.13)	(6.67)
γ	0.405	0.139	0.312	0.471	0.497	0.491
	(2.07)	(0.53)	(2.01)	(2.96)	(5.12)	(3.69)
ϕ^a	1.021	1.046	1.033	1.010	0.997	1.003
	(1.35)	(3.14)	(3.13)	(1.17)	(0.35)	(0.45)
R^2	0.630	0.695	0.661	0.765	0.747	0.755
SEE	31.69	29.12	30.47	19.71	21.55	20.63
Stratification test: (F-ratio)			0.70			0.60
Test for equality of coefficients $\beta = \gamma$: (t-ratio)	0.67	0.65	0.28	3.19	1.46	2.64

Note: t-statistics in parentheses.

[a] t-statistics refer to the null hypothesis that $\phi = 1.0$ (i.e., that the rate of housing price increase equals the rate of overall price inflation).

TABLE 4

Basic Stock Adjustment Models—Nonsymmetric Adjustment

$$H_{t+1} = \alpha^{+}\delta_{1}[H_{t+1}{}^{d} - H_{t}] + \alpha^{-}\delta_{2}[H_{t+1}{}^{d} - H_{t}] + \phi H_{t}$$

	Phoenix			Pittsburgh		
	$0 \to 1$	$1 \to 2$	Pooled	$0 \to 1$	$1 \to 2$	Pooled
α^{+}	0.364	0.349	0.357	0.158	0.095	0.126
	(5.51)	(5.32)	(7.67)	(3.50)	(1.96)	(3.78)
α^{-}	0.093	0.074	0.079	0.057	0.273	0.176
	(2.87)	(3.42)	(4.33)	(0.78)	(3.69)	(3.38)
ϕ^{a}	0.990	1.013	1.000	1.006	1.021	1.013
	(0.56)	(0.79)	(0.02)	(0.42)	(1.45)	(1.37)
R^{2}	0.640	0.705	0.670	0.762	0.747	0.753
SEE	31.29	28.64	30.03	19.81	21.53	20.72
Stratification test:						
(F-ratio)			0.69			1.82
Test for equality of coefficients $\alpha^{+} = \alpha^{-}$:						
(t-ratio)	3.43	3.81	5.27	1.04	1.69	0.69

Note: t-statistics in parentheses.

[a] t-statistics refer to the null hypothesis that $\phi = 1.0$ (i.e., that the rate of housing price increase equals the rate of overall price inflation).

quite similar for the two replications of the model; the results suggest that 12 to 16% of the gap between initial housing consumption and the equilibrium level is closed in each 6 month period. For Phoenix households, the adjustment coefficients imply that 27 to 28% of the gap is closed in a 6 month period. The coefficients indicate that housing prices increased slightly more rapidly than other prices at both locations during the 1973 to 1974 period.

An F-test permits an explicit test of the replicability of the model. The covariance test accepts the hypothesis of equality of coefficients in the two time intervals for each metropolitan area.

Table 3 provides tests of the adjustment model when the gap is disaggregated into the initial disequilibrium in housing consumption and the change in the equilibrium consumption level. With one exception, the estimated coefficients indicate that consumers adjust more rapidly to changes in their equilibrium positions than to their initial levels of disequilibrium. For the pooled Phoenix (Pittsburgh) sample, the results indicate that 31% (49%) of a change in equilibrium housing consumption is removed in the same period. In contrast, only 27% (14%) of the initial level of disequilibrium is removed. It should be noted, however,

TABLE 5

Expanded Stock Adjustment Models—Nonsymmetric Adjustment

$$H_{t+1} = \beta^+\delta_1[H_t{}^d - H_t] + \beta^-\delta_2[H_t{}^d - H_t] + \gamma^+\delta_3[H_{t+1}{}^d - H_t{}^d] + \gamma^-\delta_4[H_{t+1}{}^d - H_t{}^d] + \phi H_t$$

	Phoenix			Pittsburgh		
	$0 \to 1$	$1 \to 2$	Pooled	$0 \to 1$	$1 \to 2$	Pooled
β^+	0.382	0.353	0.370	0.160	0.103	0.158
	(5.50)	(5.26)	(7.66)	(3.74)	(2.06)	(4.99)
β^-	0.086	0.074	0.077	0.027	0.234	0.042
	(2.63)	(3.42)	(4.26)	(1.35)	(3.23)	(2.12)
γ^+	0.295	0.261	0.251	0.490	0.735	0.611
	(0.90)	(0.55)	(0.96)	(2.18)	(2.00)	(3.14)
γ^-	0.486	0.130	0.385	0.426	0.199	0.284
	(1.49)	(0.31)	(1.51)	(1.35)	(0.49)	(1.14)
ϕ^a	0.989	1.010	1.000	0.997	1.004	0.987
	(0.47)	(0.47)	(0.03)	(0.27)	(0.25)	(1.40)
R^2	0.642	0.705	0.672	0.766	0.749	0.754
SEE	31.29	28.70	30.01	19.71	21.54	20.71
Stratification test: (F-ratio)			0.46			2.11
Tests for equality of coefficients:						
$\beta^+ = \beta^-$ (t-ratio)	3.62	3.80	5.39	2.63	1.25	2.80
$\gamma^+ = \gamma^-$ (t-ratio)	0.36	0.19	0.32	0.15	0.88	0.92

Note: t-statistics in parentheses.

[a] t-statistics refer to the null hypothesis that $\phi = 1.0$ (i.e., that the rate of housing price increase equals the rate of overall price inflation).

that, with a formal test, this behavioral difference is not statistically significant in Phoenix. Again, the F-ratios reported in Table 3 indicate that the estimated coefficients are equivalent for both replications in each metropolitan area.

Tables 4 and 5 present the results when these two models are expanded to distinguish between households consuming "too much" housing and those consuming "too little" housing. In Table 4 we distinguish between the adjustment rate of households to higher levels of housing consumption and the rate of adjustment to lower levels. For the Phoenix sample, the estimates indicate more rapid adjustment of the stock of housing to its equilibrium level by those households whose current housing consumption is less than its equilibrium level than by those whose current consumption exceeds its equilibrium level. This evidence of the so called "Duesenberry

effect" is statistically significant for the Phoenix sample, but is not supported by the results from the Pittsburgh sample.

Table 5 presents the fully disaggregated stock adjustment model which distinguishes between the initial gap in housing consumption and any change in equilibrium demand, by algebraic sign.

The relevant statistical tests indicate that the speed of adjustment to changes in the equilibrium level of demand is the same whether the equilibrium demand has increased (due, e.g., to increases in income) or has decreased (due, e.g., to decreases in income).

The asymmetry in the adjustment process is more evident for households' responses to their initial levels of disequilibrium. The results generally suggest that households initially consuming "too little" housing change their observed consumption more rapidly than those initially consuming "too much" housing.

Finally, the results reported in Tables 4 and 5 again indicate that the replication test is passed in each case. Within each housing market, the coefficients of each variant of the adjustment model are identical when the model is replicated for two time periods.

5. CONCLUSION

The research reported in this paper has two objectives. First, an effort is made to characterize better the housing demand function for renter households. Second, the analysis attempts to describe the adjustment behavior of consumers in the housing market by exploring a simple model of market dynamics.

The analysis is made possible by the existence of longitudinal data on the behavior of households at several points in time in a single housing market. These data, collected for the Housing Allowance Demand Experiment in two metropolitan areas, permit an estimation of the "equilibrium" demand function for rental housing by capitalizing on information about the mobility behavior of households. The estimated demand models, which are quite consistent for both metropolitan areas, indicate an elasticity of demand with respect to current income of about 0.5 for representative households; they also provide estimates of how other demographic factors influence the demand for rental housing.

These longitudinal data permit estimation of several variants of a simple stock adjustment model of housing consumption. In the dynamic models, we hypothesize that changes in housing stock are a function of the difference between current consumption and desired consumption (the latter being obtained from the equilibrium demand equations) and of the housing price inflation in the local market.

The simple models, which view consumption changes as a function of the aggregate disequilibrium in housing consumption, appear satisfactory.

The models explain some 66 to 75% of the variation in end-period consumption; more importantly, since the data include samples drawn from two cities for two time intervals, each variant of the adjustment model can be replicated for the same households in a different time period.

The expanded versions of the stock adjustment model allow different adjustment patterns depending upon intertemporal changes in equilibrium and initial disequilibrium levels. There is some evidence, although not conclusive, that adjustments to changes in equilibrium demands are more rapid than adjustments to initial disequilibrium positions. On the other hand, tests of asymmetry in adjustment (different adjustment speeds depending upon whether a household was above or below their equilibrium demand) provide only weak evidence that adjustments to increases in demand are more rapid than adjustments to decreases in equilibrium demand.

Finally, the choice of control households from the Housing Allowance Demand Experiments (i.e., those individuals receiving no experimental treatments but from whom data are regularly collected) for this analysis is not accidental. Indeed, a major advantage of viewing the housing consumption of individual households as a dynamic adjustment process is in providing a framework for viewing the responses over time of households participating in experiments of limited duration.

Incorporating the housing allowance treatments themselves into the adjustment framework depends upon the specific aspects of the experiment. The demand experiment is actually two distinct programs: the first offers a rent subsidy that is based upon actual housing consumptions; the second is an income transfer based upon income and family composition. The first plan simply reduces the price of housing for selected households; the second plan is similar to a negative income tax plan except that certain restrictions, such as spending a designated minimum amount on rent or meeting certain quality standards, are imposed.

Within the framework of the adjustment model, the effect of the price subsidy can be analyzed directly as long as the price elasticity of demand is constant across individuals. This price elasticity can be estimated directly by using the estimated adjustment model as a maintained hypothesis and separating out the subsidy amount from the other determinants of demand.[8]

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[8] In terms of the basic stock adjustment model (Eq. 4), price reductions can be incorporated by estimating

$$H_{t+1} = \alpha[(1 + A\eta)H_{t+1}{}^d - H_t] + \phi H_t \qquad \text{(N-6)}$$

where A is the subsidy (percent of rent forgiven) offered to any household, and η is the price elasticity of demand. Equation (N-6) can be estimated by ordinary least squares with η as a parameter.

The income transfer program is more complicated. When there are no restrictions on housing expenditures or housing choice imposed on recipients, the income transfer should act the same as an increase in current income from any other source. However, because the experiment is of limited duration (and known to be so by the participants), recipients of this transfer may discount the value of the transfer (i.e., not treat it as an equivalent increase in income from other sources). Since the expected increase in housing consumption from an increase in income is known, it is possible to estimate the amount of discounting directly.[9]

Individuals who receive the transfer conditional upon a minimum rental expenditure or conditional upon the type of dwelling occupied face a different decision problem. They must decide whether or not to accept the subsidy (by meeting some restrictions) and what their new consumption level should be. Thus, the adjustment problem involves simultaneous solution of the housing consumption problem and the program participation problem. In other words, a simultaneous equations model is necessary where one of the equations involves a binary choice.

In any event, analysis of any experiment of limited duration requires an explicit representation of the dynamics of adjustment. This is especially true in the market for housing where transactions costs (psychic costs as well as out-of-pocket costs) are expected to be important. Since the housing allowance experimental program is of limited duration (2 years for analysis purposes), many of the adjustments to experimental treatments will not be completed by the end of the experiment.

Consider, for example, a change in circumstances (such as a change in income or family size or the receipt of a housing subsidy) which increases housing demand. The simple adjustment models indicate that only 45% of the total adjustment in Pittsburgh is observed by the end of 2 years; 72% of the total adjustment in Phoenix is observed by the end of 2 years. Even the expanded models, which allow for a more rapid response to disequilibrium in the period in which it occurs, imply that only 68% (73%) of the total adjustment is observed in Pittsburgh (Phoenix) after 24 months. Thus, an evaluation of the effects of an experimental program (even one which concentrates on low income households) requires explicit consideration of the adjustment path to provide estimates of the long run responses to a national program.

[9] By substituting the housing demand equation into Eq. (4) and rearranging

$$H_{t+1} = \alpha[f(Y, A) + \kappa f(\Delta, A) - H_t] + \phi H_t \qquad \text{(N-7)}$$

where Δ is the income transfer offered to any household, and κ is the discount factor which equates expected demand from experimental payments to expected demands from ordinary income. Again, Eq. (N-7) can be estimated by ordinary least squares.

APPENDIX TABLE A1

Means and Standard Deviations of Variables Used for Pittsburgh

Variable	HADE survey (1973)		Census aggregates (1969)	
	Recent movers	Control group	Central city	SMSA
Income (thousands)	4.379	5.042	8.800[a]	9.737[a]
	(1.68)	(2.09)		
Assets (thousands)	0.636	0.913	—	—
	(2.83)	(2.60)		
Education (years)	11.009	10.801	11.5[b]	12.1[b]
	(2.34)	(2.54)		
Household size	3.316	3.364	2.82	3.10
	(1.56)	(1.71)		
Age of head	34.981	42.024	—	48.13[c]
	(15.52)	(17.34)		
Black proportion	0.231	0.196	0.202	0.071
Other non-white-(Spanish)				
proportion	0.009	0.012	0.006	0.003
Contract rent	123.307	117.852	79[d]	76[d]
	(37.85)	(37.68)		
Rent includes (1 = yes)				
Refrigerator	0.142	0.122	—	—
Stove	0.196	0.182	—	—

Notes: Standard deviations in parentheses; —, data not available.

[a] Median for all families.

[b] Median for adults aged 25 and over.

[c] Estimated from midpoints of class intervals.

[d] Median for all occupied dwelling units.

APPENDIX TABLE A2

Means and Standard Deviations of Variables Used for Phoenix

Variable	HADE survey (1973)		Census aggregates (1969)	
	Recent movers	Control group	Central city	SMSA
Income (thousands)	5.224	5.356	9.956[a]	9.856[a]
	(2.21)	(2.43)		
Assets (thousands)	0.572	1.252	—	—
	(2.25)	(5.14)		
Education (years)	10.753	10.688	12.3[b]	12.3[b]
	(2.69)	(2.80)		
Household size	3.383	3.471	3.09	3.14
	(1.75)	(2.03)		
Age of head	34.080	40.702	—	45.77[c]
	(15.61)	(18.44)		
Black proportion	0.078	0.096	0.048	0.034
Other non-white (Spanish)				
proportion	0.261	0.253	0.159	1.156
Contract rent	142.097	133.783	103[d]	105[d]
	(44.23)	(49.02)		
Rent includes (1 = yes)				
Refrigerator	0.721	0.623	—	—
Stove	0.854	0.752	—	—
Air conditioning	0.946	0.868	—	—

Notes: Standard deviations in parentheses; —, data not available.

[a] Median for all families.

[b] Median for adults aged 25 and over.

[c] Estimated from midpoints of class intervals.

[d] Median for all occupied dwelling units.

APPENDIX TABLE A3

Alternative Specifications for Demand Equations for All Recent
Mover Households

Variable	Pittsburgh		Phoenix	
	(1)	(2)	(3)	(4)
Income (thousands)	4.430	4.180	6.230	6.150
	(4.03)	(3.79)	(8.26)	(8.28)
Assets (thousands)	0.440	0.840	0.240	0.102
	(0.73)	(1.31)	(0.32)	(1.39)
Education (years)	3.871	2.829	2.972	2.759
	(4.93)	(4.90)	(4.59)	(4.32)
Household size	6.652	5.750	3.613	1.852
	(5.54)	(4.50)	(3.48)	(1.71)
Black	−16.998	−16.508	−23.537	−23.626
	(4.42)	(4.30)	(3.96)	(4.04)
Other nonwhite	1.147	−0.018	−16.834	−15.902
	(0.07)	(0.00)	(4.52)	(4.34)
Age	0.237	1.569	0.046	2.756
	(2.00)	(2.33)	(0.41)	(4.79)
Age-squared	—	−0.016	—	−0.031
		(2.01)		(4.80)
Refrigerator	15.790	17.339	−5.750	−5.000
	(2.33)	(2.55)	(1.34)	(1.19)
Stove	4.333	3.645	14.044	14.777
	(0.72)	(0.61)	(2.68)	(2.86)
Air conditioning	—	—	16.872	18.627
			(2.43)	(2.72)
Constant	31.503	11.815	46.089	2.973
R^2	0.286	0.293	0.260	0.286
df	414	413	641	640
Estimated income elasticity (at point of means)	0.157	0.148	0.229	0.226
Estimated income elasticity (at SMSA median)	0.567	0.535	0.585	0.577

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