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MOVING AND HOUSING EXPENDITURE: TRANSACTION COSTS AND DISEQUILIBRIUM

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ABSTRACT

The paper emphasizes initially the effects of moving transaction costs on the potential effect of government rent subsidy programs. As a concomitant to this analysis, the paper reaffirms the low income elasticities of housing expenditure among low-income renters found by others. Moving transaction costs are high on average among renters in our sample but vary widely between geographic regions and evidently vary a great deal among families as well. By our measure, transaction costs reflect monetary and especially non-monetary gains and losses associated with moving. Moving transaction costs in conjunction with low income elasticities make government lump-sum transfers very ineffective in increasing housing expenditure among low-income renters.

A dollar of unconstrained transfer payment would increase housing expenditure by only 2 to 7 cents in the two cities in our data set. Minimum rent plans, that make the transfer payment conditional on spending at least a minimum amount on rent, have larger effects on average than unconstrained transfers. Typical programs might increase rent by 10 to 30 cents per dollar of transfer payment. But families who spend the least on rent are also those least likely to benefit from the minimum rent programs. To obtain payments under these plans, families who would otherwise spend less than the minimum must surmount the transaction costs associated with moving and must also reallocate income to favor housing in proportions that may be far from their preferred allocations. Thus only a small proportion of families with initial market rents below the minimum will ultimately participate in the programs. And of the total payments to these families, 15 to 32 percent is deadweight loss, according to our estimates. In addition, we find that because moving transaction costs and income elasticities vary widely among regions, the effects of any given government program are also likely to vary greatly from one region to the other.

As a fortuitous benefit of the housing allowance demand experiment data that we used, we were also able to check our model results against experimental results. The model predictions and the experimental results correspond quite closely. The differences that are found can apparently be explained in large part by the impact of self-selection on the estimated experimental treatment effects. The self-determination of enrollment and the attrition inherent in the estimated experimental effects seriously detract from the potential benefits of experimental randomization. Therefore our model estimates may be more reliable than the experimental ones in this instance. Of course this judgment depends in large part on the experiment having been done so that we could check our model predictions against the experimental outcomes.

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MOVING AND HOUSING EXPENDITURE:
TRANSACTION COSTS AND DISEQUILIBRIUM

by

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Better living conditions for low-income families is the collective goal of many government programs. Better housing is the particular goal of government-subsidized housing programs. These subsidies take two general forms. The government may build housing and rent it to low-income families at less than market prices or it may provide housing allowances directly to low-income families. An allowance may be a percent of rent, or it may be a lump sum payment not conditioned on rent. Still another form of allowance is a lump-sum payment conditional on spending some minimum amount on rent. Whatever the form of the allowance, the apparent goal is that it will induce low-income families to live in better housing than they would otherwise choose. Implicit in this goal is that more expensive housing is also of higher quality. No matter what the inducement, however, for a family to significantly improve its housing almost invariably requires moving from one location to another. This is likely to involve a large transaction cost. A primary emphasis of our work is an analysis of the magnitude of transaction costs and their implications for the effects of government subsidy programs.

We shall concentrate our analysis on lump-sum transfer programs and in particular the minimum rent plan. Both plans are sometimes called "housing gap" schemes because the payment is thought of as making up the difference between the cost of modest housing and the proportion of its income that a family might be expected to devote to housing. The lump-sum plans as well as percent of rent subsidy schemes were the subject of the recent Experimental Housing Allowance Program and in particular the demand component of the program, called the Housing Allowance Demand Experiment.[1] Indeed, a form of gap plan is currently being proposed by the Administration.[2]

We shall see that this plan potentially involves substantial deadweight loss even without consideration of moving costs. To take advantage of the subsidy, many families may have to devote a greater proportion of their income to rent than they would otherwise choose. As a consequence the marginal units of rental housing purchased by those who receive housing payment subsidies is often valued at less than the payment. The transaction costs associated with moving reduce further the potential gain from this plan relative to the gains that could be obtained with simple unconstrained lump-sum transfers.

It is not, of course, logically necessary to allow explicitly for moving to obtain meaningful estimates of housing expenditure. Moving, or staying, is in some sense what takes place in the black box between one expenditure level and another. Many questions can be addressed without observing <u>how</u> expenditures are increased; that is, without monitoring move and stay decisions explicitly. We simply realize that observed changes in housing expenditure are due in large part to these decisions.

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1. See, for example, Friedman and Weinberg [1980], 1930b] and Bradbury and Downs [1981].

2. The Administration proposal is to convert the section 8 housing program to one like the minimum standards plan of the Housing Allowance Demand Experiment. This is like the minimum rent plan except that the lump-sum payment is made only if the housing meets certain physical standards.

But because moving is a major and sometimes costly decision in its own right, as well as bearing a close correspondence with housing expenditure, we are motivated to investigate more precisely the decision to move or stay and its relation to expenditure. Analogous "enabling" mechanisms are associated with many other expenditure decisions. For example, it may be necessary to change cars to spend substantially more for transportation by car. The transaction costs associated with moving, however, seem potentially to be exceptionally large. Therefore, adjustments in housing expenditure to changes in family status--like income--may be relatively slow.

We shall base our estimates on data from the housing allowance demand experiment, although not with the intent of analyzing the experimental results. The experiment does provide, however, data on a random sample of low-income families in two cities, Phoenix and Pittsburgh. For our purposes, the important aspect of the experimental survey is its longitudinal nature. Participants in the experimental survey were followed for three years. In particular, we are able to observe changes in rent (moving) between one period and the next.

Our plan is to estimate a model of housing expenditure jointly with moving decisions. Then based on the parameter estimates of the model we simulate the effects of lump sum and minimum rent housing subsidy plans. The deadweight loss associated with the minimum rent plan is given particular attention. The basic idea of our model, as well as its statistical implementation, is that families *move* if the advantages from moving outweigh the transaction costs associated with moving. Jointly with moving we estimate a preferred rent function, with preferred rent only observed if persons move (and then with a deviation due to "maximization" error). It is based on the proposition that individuals have some preferred level of housing expenditure. We start by thinking of a preferred level if there were no transaction costs--like changing neighborhood--associated with changing housing expenditure. Then we think of persons choosing to move if the value gained by changing housing expenditure outweighs the transaction costs associated with moving. We recognize that the adversity to moving or the propensity to move may vary among individuals. To accommodate this possibility, we allow for a moving transaction costs parameter that is random. The model and the estimation procedure are described in Section I. Estimates are based on a rent function together with an associated utility function describing preferences over the allocation of income between housing and other goods. It is the preference function that permits an evaluation of the potential gain from moving.

We base initial estimates on the experimental controls, who were not assigned to a treatment group but were surveyed over the course of the experiment. But the experimental nature of the data allows us to check our results in some respects. First, we can obtain analogous estimates based on families in the minimum rent treatment group, who, unlike the controls, faced discontinuous budget constraints. Because we would like to make predictions for persons facing this type of plan, we are motivated to check parameter estimates based on persons subject to this plan with the estimates based on the control group. Second, we are able, using our control group estimates, to make predictions of the effects of the treatment plans on persons assigned to those plans and compare them with the observed experimental treatment effects. Although for reasons to be explained below, this does not provide an unambiguous test of our model, it does provide a substantial external check of its validity. The parameter estimates are presented in Section II. Comparison of experimental treatment effects with estimated treatment effects based on our model are presented in Section III. The simulated effects of selected rent subsidy programs together with deadweight loss calculations are shown in Section IV.

As a concomitant to estimation of rent jointly with moving, we are also able to provide estimates that under certain assumptions reflect preferred rent, given income and other family characteristics. This is true to the extent that families choose a "desired" level of rent when they move (albeit with error). In this sense, our estimates might be given a "long run" or "permanent" interpretation. Desired rent would not necessarily be observed at a point in time, not even on average, if the disequilibrium created by the moving transaction costs means that observed rents are not optimal.

Our results may be summarized briefly. The average family in our sample would forego \$60 per month in income to avoid moving. The large transaction costs associated with moving primarily reflect nonmonetary costs. Large average differences between the two cities in our sample suggest that market and cultural factors may create very different barriers to moving in different locations. We also estimate a rent disequilibrium term, representing the deviation between rent when families are first observed and the rent they would prefer given their incomes and other family attributes, which may have changed since the observed rent was chosen. A large disequilibrium value is associated with a greater likelihood of moving. Finally we find low elasticities of rent with respect to income, consistent with the finding of other investigators. And we find that elasticities are quite different in the two locations in our sample.

The low income elasticities together with the transaction costs of moving mean that the effect of income transfers on rent and are very small in general and the differences among cities suggest that the same program could generate quite different effects in different locations. In particular, minimum rent plans that condition the transfer payment on meeting a minimum rent requirement have a relatively small effect on families with chosen market rents below the minimum, the families that the plan is most intended to affect. The misallocation of resources associated with changing the proportion of income devoted to housing, together with the moving transaction costs are such that most families will not increase rent enough to receive the payment. Families who do move are likely to be those with low transaction costs.

Our estimates are based on experimental control families. The validity of the model is supported by a close correspondence between experimental treatment effects and predictions of these effects based on our model. The major difference between our estimates and the experimental treatment effects appears to be explained by the self-selection and attrition associated with the experimental treatment group. Persons who knew that they would not move to obtain transfer payments apparently were much less likely to accept enrollment in the experiment when it was offered and were much more likely to drop out over the course of the experiment.

Finally, 15 to 32 percent of payments to families who would otherwise spend less than the minimum is deadweight loss. In addition, to the extent that the goal of transfer programs is to increase rent, they are in general ineffective. Only about 2 to 7 percent of unconstrained transfer payments to low income renters are used to increase rent. Rent increases under minimum rent programs range from 8 to 69 percent of payments, in our selected simulations, depending on the specification of the plan and the geographic location.

I. THE MODEL AND ESTIMATION

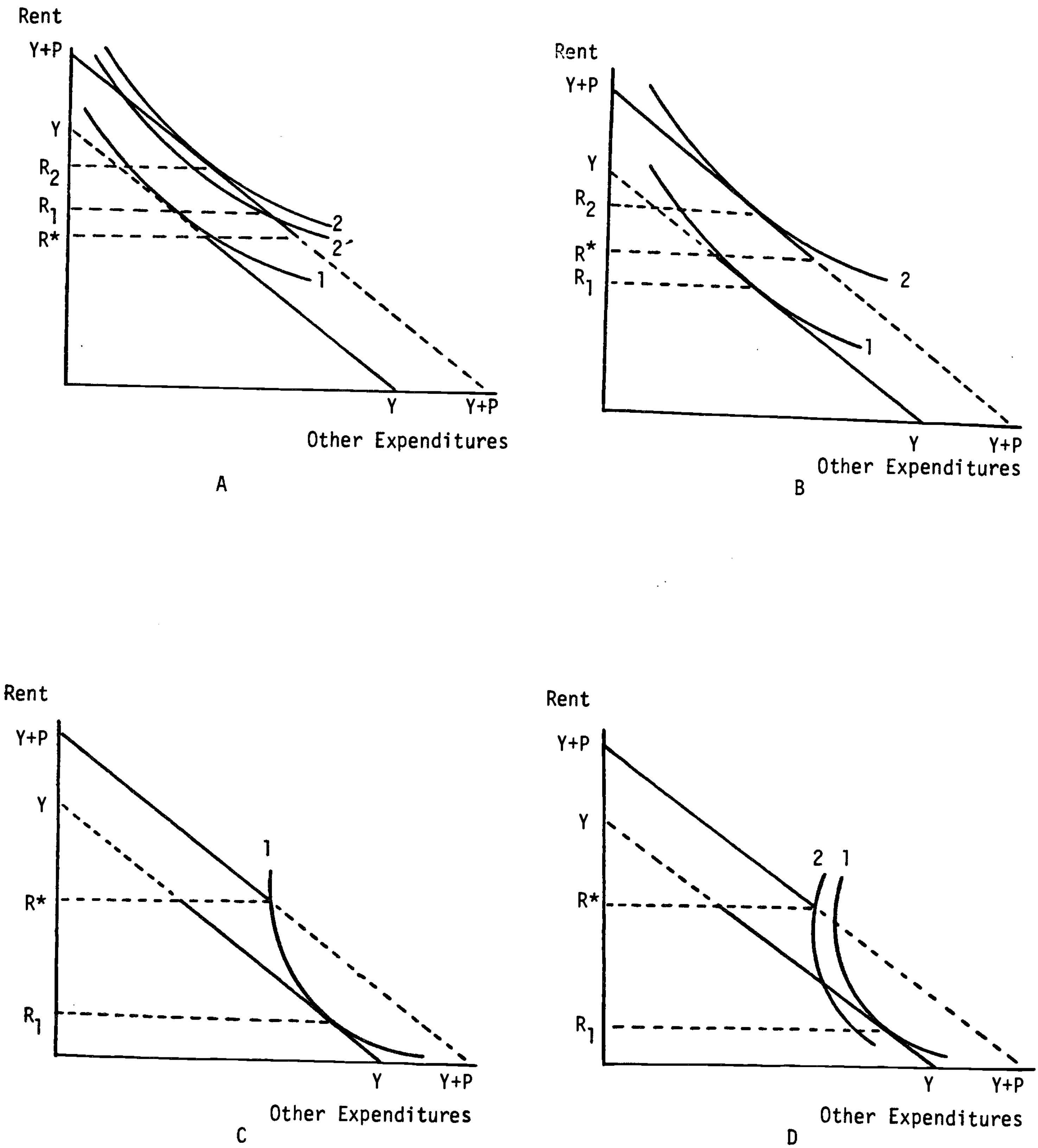
A. The General Idea

We shall motivate the idea by considering persons facing a minimum rent subsidy. We will see that our approach is not at all peculiar to this particular plan, but that consideration of the budget constraint implied by this plan helps to make the basic idea clear. The more formal presentation in the next section will take a more general approach and then explain how it would be applied in the special case of the minimum rent plan.

We begin by considering the alternatives faced by several hypothetical individuals. The preferences of each are represented by the indifference curves on one of the graphs of Figure 1. In each of the graphs the inner line (YY) is intended to represent an initial ($1^{\underline{st}}$ period) budget constraint; and the broken solid line a subsequent ($2^{\underline{nd}}$ period) constraint. In the second period, a payment P is received if at least an amount R^* of income is devoted to rent. The two budget constraints are drawn to coincide below the minimum rent requirement R^*. This would be logically true only if $1^{\underline{st}}$ period family income were equal to income (excluding the subsidy payment P) in the second period.

The family represented in graph A of Figure 1 is presumed to spend more than R^* on housing in the first period (at the tangency of YY and the indifference curve labeled 1). If there were no costs associated with moving, this family would presumably spend considerably more for housing in the $2^{\underline{nd}}$ period (the tangency of indifference curve 2 and the

Figure 1


Rent
Y+P
Y
R2
R1
R*
2
2′
1
Y
Y+P
Other Expenditures
A
Rent
Y+P
Y
R2
R*
R1
2
1
Y
Y+P
Other Expenditures
B
Rent
Y+P
Y
R*
R1
1
Y
Y+P
Other Expenditures
C
Rent
Y+P
Y
R*
R1
2
1
Y
Y+P
Other Expenditures
D

outer solid line). But the gain from moving is represented not by the differences between 1 and 2, but by the difference between 2′ and 2. The family receives the payment P even if it doesn't move. The family must presumably decide whether the gain to be had by increasing its rent from R_1 to R_2, with a concomitant reduction in expenditures for other purposes, outweighs the costs associated with moving. For this family, the only benefit from moving is reallocation of expenditures among housing and other goods and services.

The family represented in B receives the payment P only if it increases its rent. If this family moves, it would presumably prefer to spend R_2 for housing. Its gain is represented by the difference between 1 and 2. By moving, this family may benefit not only from a reallocation of expenditure, but from an increase in total expenditures as well.

If a family values housing versus other goods according to the curve 1 in C, it would gain nothing by moving. If it were not for moving costs, it presumably would be indifferent between spending R_1 for housing out of income Y and spending R^* out of income Y + P.

The greatest value attainable by the family represented in D is the same in both periods. In each period preferred housing expenditure would be R_1. If the family were to spend enough on housing to obtain the payment P, it would be worse off, even without moving costs; as indicated by the difference between values associated with curves 1 and 2. The gain from increased housing expenditure would be offset by the reduction in expenditure for other purposes.

These examples suggest that the likelihood that a family will move when faced with the minimum rent subsidy depends on the relative value that it attaches to housing versus other expenditures. Knowledge of this tradeoff allows, and is necessary for, evaluation of the potential gain from moving. But, there does not appear to be a simple relationship between first period rent and the potential benefit from moving, although it would seem that the greatest gains may be available to persons whose initial rent is below, but close to R^*. Persons who spend more than R^* on housing in period 1 may have relatively little to gain by moving; and persons who spend far less than R^* may have nothing to gain at all. The formal approach will thus be to think of the probability of moving as a function of the expected gain. Expected gain will in turn depend on initial housing expenditure and the second period expenditure possibilities given by the budget constraint.

It is important to keep in mind that persons may move for many reasons that are unrelated to the subsidy. Indeed, these other reasons may dominate the effects of the payment P, or the possibility of obtaining it by moving. Families may, for example, move because of increases or decreases in income, other than subsidy payments; or because of changes in family size. And, it is important to understand that although we can make the probability of moving a function of observed family characteristics, there are likely to be many reasons for moving that we cannot observe or quantify explicitly. A family may want to move to a better school district, or it may have to move because its landlord stops renting. Or, the family may simply be tired of living in the same place. There is likely to be considerable randomness in moving, given observed family characteristics and subsidy plans. Indeed, unobserved effects may dominate the effect of changes in observed family characteristics or the effect of subsidy plans. This possibility is supported by the observation that among persons in our data set controls move almost as much as persons who receive subsidies. Thus, in the formal model that follows we will not restrict our emphasis only to the effect of subsidies; but we will account for them.

B. A Formal Stochastic Model of Moving.

The basic idea of our model is that persons move if the gain from moving outweighs the transaction costs of the move. Although this idea is quite general, the specific model that we use is conditioned to some extent on the nature of the data we shall use. The most important aspect of the data is that they pertain to individuals all of whom face the same housing price schedule. They all face the same housing market. Thus differences in housing expenditure among families in our sample are due to differences among the families in "taste" for housing and other random components, not differences in the price of housing. Taste for housing is presumed to vary among individuals because of differences in family attributes such as income and family size and possibly because of unmeasured determinants of preferences for housing versus other goods as well. We have in mind individuals who must decide how to allocate their budgets between housing (rent) and other goods. One can think of housing and other goods as measured in quality units which incorporate not only the physical characteristics of the housing unit itself, but attributes such as parks and distance to the central city as well. The question then is how many units of housing to purchase. In this sense, more units of housing may reflect a larger house, a more desirable neighborhood, easier access to the central city, or other characteristics associated with a particular housing choice.[1]

1. Our data do include a subset of persons who face different housing prices because of a percent of rent subsidy plan with the percent subsidy varying among families. Although we could obtain estimates based on this group, we have no analogous variation in market prices. In addition, in practice our data pertain to two housing price schedules because families in the sample live in one of two cities. We shall take account of differences between the cities either by using a single dichotomous variable to distinguish them or by separate estimation for each city.

The outcome that we observe is expenditure for housing, R. Thus the first condition for our specification is that it fit the data, that the expenditure function fit the observed relationship between rent and family characteristics. Although we shall rely also on an associated "utility" function, it is only the expenditure relationship that allows us to make inferences about the parameters of the utility function. In practice, the relationship between rent and income Y is very closely approximated by the functional form

$$R = \delta_0 Y^{\delta_1} . Y \,, \tag{1}$$

where the proportion of income spent on rent is $\delta_0 Y^{\delta_1}$, and the income elasticity of rent is $1 + \delta_1$.

Because we observe only expenditure for housing, not its quantity or quality separately, we shall think of preferences defined over the space of rent R and expenditure on other goods Y - R. Associated with the expenditure function (1) is a preference function V given by

$$V(Y - R,R) = (Y - R)^{1-\delta_0 Y^{\delta_1}} (R)^{\delta_0 Y^{\delta_1}} \tag{2}$$

Maximization of V with respect to R yields the rent expenditure function (1).[1]

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1. Measured in quality units of value 1, we could think of a utility function, $U(Z_1,Z_2) = Z_2^{1-\delta_0(Z_1+Z_2)^{\delta_1}} Z_1^{\delta_0(Z_1+Z_2)^{\delta_1}}$, that is maximized subject to the constraint $Z_1 + Z_2 = Y$. In this sense, V is obtained by substituting the constraint into U. Note also that V is a variant of a simple Cobb-Douglas function. It differs from that one in a major respect, however; it is not homothetic and thus does not imply constant budget shares, a property that we know is rejected by the data. The data also are inconsistent with the transposed Cobb-Douglas function represented by the Stone-Geary system which also implies linear expansion paths but from a displaced origin. The function V is a variant of the one used by Hausman and Wise [1980] with which we shall make some further comparison below. We shall also see that to make moving a function of the potential gain in utility we must use the direct utility function; thus a specification without a closed form direct utility function will not do in this case.

We specify δ_0 as a function of family attributes X and possibly unmeasured attributes η, with

(3) $$\delta_0 = X\delta + \eta \ .$$

We also interpret equation (1) to be preferred rent, with observed rent deviating from this optimum according to the random term ε, so that

(4) $$R = \delta_0 Y^{\delta_1} \cdot Y + \varepsilon \ .$$

The maximization error ε may arise for example because it is not possible to find just the right housing or because of incomplete information at the time that rent decisions are made. The parameter δ_1 is taken to be the same for all individuals, with random taste variation entering through η in δ_0.[1]

To incorporate moving, suppose that the value in period two associated with period one housing expenditure is $V_{12} = V(Y_2-R_1,R_1)$ and the value in period two associated with optimal housing expenditure in period two, when X or Y may be different from their period one values, is $V_{22} = V(Y_2-R_2,R_2)$. If there were no transaction costs to moving, presumably the family would move if V_{22}/V_{12} were greater than 1; or if $\ln V_{22} - \ln V_{12}$ were greater than zero. We shall let the transaction costs of moving be reflected in a random factor M such that the ratio of the values of moving to staying is given not by V_{22}/V_{12} but by $V_{22}/(V_{12}\cdot M)$.[2] We let the gain from

1. A logical alternative would be to let δ_1 be random, but this complicates the evaluation of the moving probability, given the specification of our preference function V.

2. An alternative interpretation is to think of moving as incorporated explicitly in the utility function with $V(Y-R,R,M) = V(Y-R,R)\cdot M$, where M takes on a value presumably different from 1 if the choice doesn't involve moving. Then $V(Y_2-R_2,R_2,M) = V(Y_2-R_2,R_2)$, if the choice does involve moving.

moving be given by g, with the family moving between periods one and two if

(5) $$g = \ln V_{22} - \ln V_{12} - \ln M > 0 ,$$

with the probability of moving given by $\Pr[g > 0]$.[1]

If we assumed a distribution for ln M and if we knew δ_0 and δ_1, which enter V_{22} and V_{12}, we could indeed estimate (5) directly yielding an estimate for the mean of ln M and in theory, its variance as well. We describe below, however, models that yield estimates of the parameters δ_0 and δ_1 along with the mean of the transactions cost parameter M. We begin with a specification with δ_0 non-random, that is with $\eta = 0$. Then we shall allow δ_0 to be random. Finally, we extend the specification to allow estimation for persons facing a minimum rent subsidy plan. We develop this last specification in the first instance to allow prediction of rent and moving under

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1. An alternative approach is to think of transaction costs as reflected in a discount of the value of other expenditures if one moves. We might then have $g = \ln V_{22}(Y_2-T-R_2,R_2) - \ln V_{12}(Y_2-R_1,R_1)$. This specification, however, makes the discount for moving independent of other attributes like income. And it is difficult to allow T to be random because of the non-linear specification of V. One could still, however, specify a probit equation by including an additive random term ν with $g = \ln V_{22}(\cdot) - \ln V_{12}(\cdot) + \nu$. Still another alternative in this same spirit but that allows the transactions cost effect to vary with income is to set $g = \ln V_{22}(\lambda(Y_2-R_2),R_2) - \ln V_{12}(Y_2-R_1,R_1)$, where λ is the transaction costs effect, presumably less than 1. This specification leads to $g = \ln V_{22}(Y_2-R_2,R_2) - \ln V_{12}(Y_2-R_1,R_1) + (1-\delta_0 Y_2^{\delta_1})\ln\lambda$, which could be estimated as a probit equation with the addition of a random term. This specification makes the other-expenditure-equivalent transaction costs of moving an increasing function of other expenditure. Our specification assumes that the willingness to move is proportional to the gain in utility; to be willing to move the proportional gain in utility must be M, where M is presumed to be random across individuals.

We also could have used a continuous time hazard approach to model moving, but it is not straightforward to elide this model with joint estimation of a rent function within the utility maximizing framework that we have used.

this plan, but also to check our estimates for controls with those based on families facing this subsidy plan.[1]

1. A Specification with δ_0 Non-Random.

Recall that preferred rent is taken to be $R = \delta_0 Y^{\delta_1} \cdot Y$, with δ_0 a function of individual attributes X. If δ_0 is non-random ($\eta = 0$), it is simply given by $\delta_0 = X\delta$. Observed rent in period one is then

$$(6) \qquad R_1 = \delta_0 Y_1^{\delta_1} \cdot Y_1 + \varepsilon_1 = (X_1\delta) Y_1^{\delta_1} \cdot Y_1 + \varepsilon_1 ,$$

where ε_1 is the random deviation from preferred rent in period one. Preferred rent in period two is only observed for persons who move and then only with error, so that

$$(7) \qquad R_2 = \delta_0 Y_2^{\delta_1} \cdot Y_2 + \varepsilon_2 = (X_2\delta) Y_2^{\delta_1} \cdot Y_2 + \varepsilon_2 ,$$

where ε_2 is the deviation from optimum rent in period two. Note that δ_0 is allowed to change between periods one and two with changes in the vector of family attributes X. Note also that ε_1 and ε_2 should not necessarily be interpreted symmetrically.

In both periods ε represents maximization errors that result from the inability to find just the "right" housing. In addition, ε_1 also reflects deviations from optimal rent due to changes over time in X or Y. In other words, many first period families may be in disequilibrium because their "preferred" housing level may have changed over time, but they have not moved to adjust actual housing expenditures accordingly. We refer to this component of ε_1 as disequilibrium error, with $\varepsilon_1 = \alpha + e_1$ where α is the

1. The development follows closely the procedure outlined in Wise [1977a, 1977b].

disequilibrium component and e_1 is the maximization error. In contrast, we assume second period rent is, with the exception of the maximization error, optimally chosen.[1]

As above, the family moves between periods one and two if the potential gain from adjusting housing expenditure to reflect changes in family attributes outweighs the moving transaction costs, that is if

$$g = \ln V_{22} - \ln V_{12} - \ln M > 0 .$$

Suppose that ln M is distributed normally with mean m and variance σ_m^2.

$$\ln M \simeq N(m,\sigma_m^2) . \tag{8}$$

It is important to realize that while we refer to M as a transaction "cost" and presume that its mean value is positive, it not only is likely to vary among families, but is not necessarily positive for all families.[2] It of course includes the monetary cost of moving. It also includes psychic costs such as loss of friendships or changing schools. With this interpretation, it is clear that given the family attributes that we measure, the preference comparisons that we make may exclude some of the benefits as well as some of the costs of moving. For example, a family could move to take advantage of different schools, where the advantage perceived by the family may not be reflected in rent.

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1. Alternatively, this asymmetric treatment of ε_1 and ε_2 arises because we observe R_1 for the entire sample--some of whom have moved recently and some not--and thus the R_1 that we observe is not necessarily at the preferred level when we observe it. In contrast we only have information on R_2 for families that move between periods, that is, for families that have adjusted actual expenditures to "preferred" or optimal levels, according to our interpretation.

2. Note also that transaction "costs" are not measured in dollar units, but we are able to convert our estimates to income equivalents.

To proceed, suppose that R_1 is given. There are two possible outcomes in the second period:

1. R_2 is observed and the family moves $(g > 0)$,
2. R_2 is unobserved and the family doesn't move $(g < 0)$.

That is, each family faces two alternatives: it can not move and continue to spend R_1, or it can move and spend R_2. Following this terminology, R_2 is observed only if a family moves. Expenditure for rent in the second period is still observed, of course, but we assume for the moment that it is the "same" as rent in period 1.[1] Given R_1 and R_2, the probabilities of moving and not moving are given, respectively, by

$$\Pr(g > 0|R_1,R_2) = \Phi\left[\frac{\ln V_{22} - \ln V_{12} - m}{\sqrt{\sigma_m^2}}\right] ,$$

(9)

$$\Pr(g < 0|R_1,R_2) = 1 - \Phi\left[\frac{\ln V_{22} - \ln V_{12} - m}{\sqrt{\sigma_m^2}}\right]$$

where $\Phi[\cdot]$ is the standard normal distribution function.

Now consider the joint distribution of R_1,R_2, and g, denoted by the density function $h(R_1,R_2,g)$. It can be written as,

$$h(R_1,R_2,g) = f(R_1)\cdot f(R_2|R_1)\cdot f(g|R_1,R_2) , \tag{10}$$

Consider the first possibility above; that is, that the family moves and spends R_2 for rent. The likelihood of this occurring is given by,

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1. Or its equivalent after accounting for inflation. All rent and income figures in our analysis are in period 2 dollars. There may be some increase in expenditure due to upgrading of existing housing without moving, but summary data suggest that this effect is small relative to rent changes associated with moving.

$$(11) \quad P_1 = f(R_1)f(R_2|R_1)\cdot Pr(g>0|R_1,R_2) = f(R_1)f(R_2|R_1)\cdot\Phi\left[\frac{\ln V_{22} - \ln V_{12} - m}{\sqrt{\sigma_m^2}}\right]$$

To find the probability of not moving, we need to consider the marginal density of g; in particular, the probability that $g < 0$. Because R_2 is not observed for non-movers, we need to find the probability that $g < 0$ for each possible value of R_2, given R_1, and "add them up." This can be done by integrating out R_2 from the joint density of R_2 and g, given R_1. This is, of course, just a way of taking account of the fact that R_2, the desired level of second-period rent, is not observed for families who don't move. The probability of not moving is then given by,

$$P_2 = f(R_1)\int_{R_2} f(R_2|R_1)Pr(g < 0|R_1,R_2)dR_2$$

(12)

$$= f(R_1)\int_{R_2} f(R_2|R_1)\left\{1 - \Phi\left[\frac{\ln V_{22} - \ln V_{12} - m}{\sqrt{\sigma_m^2}}\right]\right\} dR_2 \; .$$ [1]

We assume throughout that M is distributed independently of ε_1 and ε_2.[2]

1. Because V is a non-linear function of R, we cannot simplify this expression further. Note also that R_2 must here be formally restricted to lie between 0 and Y, because the logarithms of Y_2-R_2 show up in the expression V_{22}.

2. This means, for example, that a family's cultural ties to a community are independent of the sign of the maximization error ε. Below we also assume that cultural ties, etc. are independent of random preferences for housing captured by the taste disturbance η. Although this latter assumption seems more problematic to us, predictions presented below tend to support it. In particular, we are able to predict well the housing expenditures of members of the experimental treatment group who moved, even though the treatment group was composed disproportionately of persons with low moving costs, relative to members of the control group. We shall say more about this in Section III.

In practice we have set $\sigma_m^2 = 1$. We assume that ε_1 and ε_2 are distributed normally with common variance σ_ε^2 and independent of M. In estimation of this model with $\eta = 0$, we also have allowed ε_1 and ε_2 to be correlated according to the parameter ρ_ε. That is, we allow individual-specific determinants of housing expenditure to be reflected in these disturbance terms. (We shall assume below that these effects are captured in η.) More detailed specification of the elements of equations (11) and (12) are provided in Appendix A.

If N_1 persons move, and N_2 don't, the log-likelihood function for $N_1 + N_2 = N$ persons is given by

$$\ln L = \sum_{i=1}^{N_1} \ln P_{1i} + \sum_{i=1}^{N_2} \ln P_{2i} , \tag{13}$$

where P_1 and P_2 are defined by equations (11) and (12). Maximization is with respect to δ (the parameters in $\delta_0 = X\delta$), the income elasticity parameter δ_1, the mean transaction cost parameter m, and the distribution parameters σ_ε^2, and ρ_ε. We turn next to a more realistic specification with a random "taste" parameter η.

2. With the Taste Parameter δ_0 Random.

A shortcoming of the above specification is the assumption that the preferred level of rent is exactly determined by measured family attributes. We now relax this assumption by letting δ_0 contain a random component (η) that captures unobservable determinants of housing preferences. If δ_0 is random, then rents in periods one and two (if R_2 is observed) are given by

$$R_1 = \delta_0 Y_1^{\delta_1} \cdot Y_1 + \varepsilon_1 = (X_1\delta + \eta) \cdot Y_1^{1+\delta_1} + \varepsilon_1, \text{ and}$$

(14)

$$R_2 = \delta_0 Y_2^{\delta_1} \cdot Y_2 + \varepsilon_2 = (X_2\delta + \eta) \cdot Y_2^{1+\delta_1} + \varepsilon_2 ,$$

where η is the random component of the taste parameter δ_0. In this case preferred rent depends on the random δ_0 (through η) and so then does the probability of moving. Thus in this case we must integrate over possible values of δ_0. The expressions for P_1 (moving and observing R_2) and P_2 (not moving) may be written as

$$P_1 = f(R_1) \cdot f(R_2|R_1) \cdot \int_{\delta_0} f(\delta_0|R_1,R_2) \cdot Pr[g > 0|\delta_0,R_1,R_2] d\delta_0 ,$$

(15)

$$P_2 = f(R_1) \cdot \int_{R_2} f(R_2|R_1) \cdot \int_{\delta_0} f(\delta_0|R_1,R_2) \left\{1 - Pr[g > 0|\delta_0,R_1,R_2]\right\} d\delta_0 dR_2 .$$

Further details are provided in Appendix A.

In this specification we treat η as a random individual specific effect that does not change over time. And we now treat ε_1 and ε_2 as uncorrelated random deviations from optimum housing expenditure. That is, we essentially assume a variance components specification with the disturbance term given by $\eta \cdot Y_t^{1+\delta_1} + \varepsilon_t$, instead of the usual specification $\eta + \varepsilon_t$.

3. Estimation With the Minimum Rent Subsidy.

The models outlined above will allow us to use the observations on experimental controls to estimate the parameters of the rent expenditure function and the preference function, as well as the magnitude of transaction costs. These estimates can then be used to predict responses to various subsidy schemes. In particular, a primary objective of our analysis is to estimate the deadweight loss associated with minimum rent subsidy schemes. But the housing allowance demand experiment included experimental plans of this kind. Thus using these data we can also estimate our model for persons who actually faced such a subsidy, in particular the discontinuous budget constraint created by it. There are two reasons for obtaining estimates using these data, in addition to the estimates based on controls. One is that setting up the estimation routine for this case facilitates the predictions and the calculation of deadweight loss under this scheme. The other reason is that it allows us to check the parameter estimates obtained for controls with those obtained for persons actually facing this plan. As mentioned above, we will also compare the experimental results with predictions based on our parameter estimates for controls. To obtain estimates when the budget constraint is discontinuous we need to add some additional concepts to those set forth above. The development here with respect to the discontinuous budget constraint is similar to that set forth in Hausman and Wise [1980], but that analysis used only data for a single period (not taking account of R_1) and did not treat moving. In addition, the utility specification that we use is different from that used by Hausman and Wise. As it turns out, our specification fits the data better than the one used there.

We begin by considering the graph in Figure 2 that depicts the choices faced by persons subject to a minimum rent subsidy. The solid discontinuous straight line represents the budget constraint faced by a person with income Y. It has negative slope 1 because any person in our sample can give up a dollar in expenditure on other goods and obtain the same addition to housing, measured in quality units. If the family spends at least R^* for rent it receives the payment P.[1] The dashed lines going in a northeasterly direction from the origin represent the relationship between optimal rent and income for persons with given values of δ_0. That is, they represent the locus of tangencies between successively higher budget constraints and

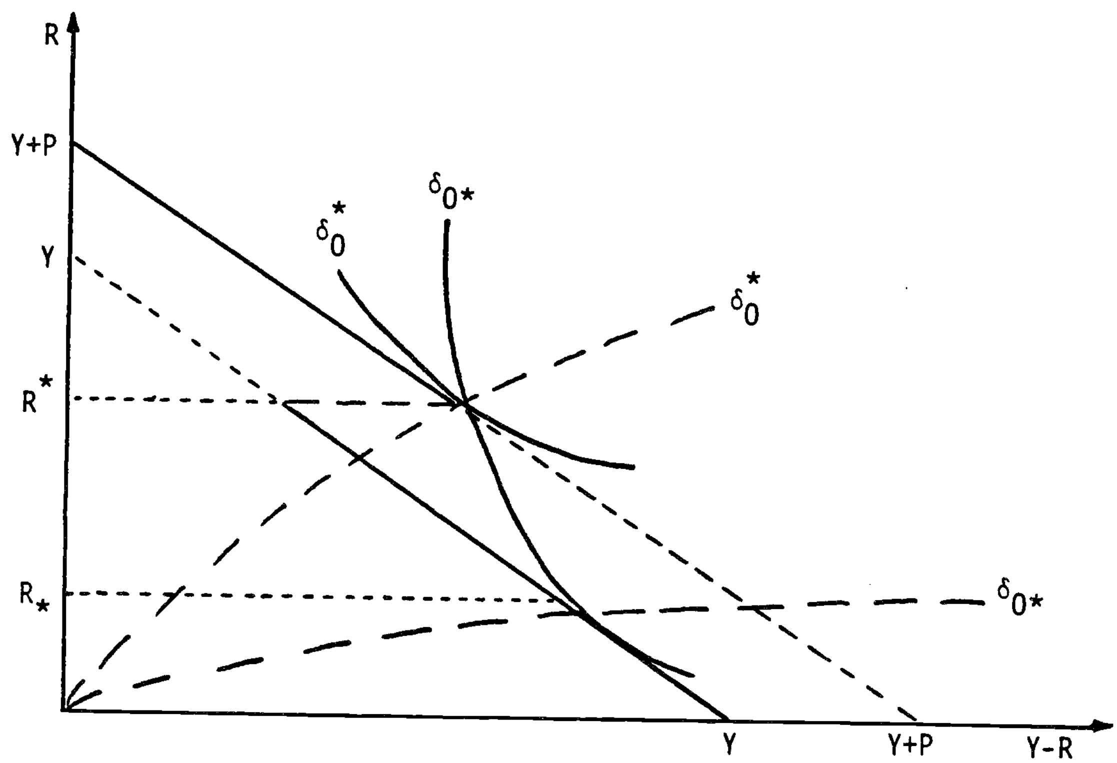

Figure 2

the family of indifference curves distinguished by a particular value of δ_0. A person with $\delta_0 = \delta_0^*$ would choose to spend R^* for rent when faced with the budget constraint shown and would attain the utility level corresponding to the indifference curve also labelled δ_0^*. On the other hand, a person with taste parameter δ_{0*} would be indifferent between spending R_* for rent with $Y - R_*$ for other goods and R^* for rent with $Y + P - R^*$

1. In practice, P depends on family income; it is highest for low-income families and becomes zero if income is large enough.

for other goods, as indicated by the indifference curve labelled δ_{0*}. Persons with $\delta_0 > \delta_0^*$ would prefer to spend more than R^* and persons with $\delta_0 < \delta_{0*}$ would prefer to spend less than R_*. Those with $\delta_{0*} < \delta_0 < \delta_0^*$ would prefer to spend R^*.

To describe the likelihood of an observed R, it is necessary to account not only for these optimal choices but for the deviations from the optimum as well. These are indicated by the ε terms in our analysis above. Also this description has dealt only with the discontinuous budget constraint. Persons during the first period of our analysis faced a linear budget constraint like YY, with the discontinuous one faced only in the second period. We also have said nothing about moving in this context. We shall proceed by first describing the likelihood of R_1 in period one and R_2 in period two if there were no transaction costs. Then we add again the presumption that R_2 will only be observed if the gain associated with shifting from R_1 in period one to R_2 in period two outweighs the transaction costs of moving.

Without the transaction costs, the likelihood $l(R_1,R_2)$ of observing housing expenditure R_1 in period one and R_2 in period two would be

$$(16)\qquad l(R_1,R_2) = \Pr\left\{\begin{array}{lll} R_1 = \delta_0 Y^{1+\delta_1} + \varepsilon_1, & \delta_0<\delta_{0*}, & R_2 = \delta_0 Y^{1+\delta_1} + \varepsilon_2;\text{ or} \\ R_1 = \delta_0 Y^{1+\delta_1} + \varepsilon_1, & \delta_{0*}<\delta_0<\delta_0^*, & R_2 = R^* + \varepsilon_2;\text{ or} \\ R_1 = \delta_0 Y^{1+\delta_1} + \varepsilon_1, & \delta_0^*<\delta_0, & R_2 = \delta_0 (Y+P)^{1+\delta_1} + \varepsilon_2. \end{array}\right\}$$

The three terms in this expression can be written respectively as

$$f(R_1)\cdot f(R_2|R_1)\cdot\int_{-\infty}^{\delta_{0*}} f(\delta_0|R_1,R_2)d\delta_0$$

$$(17) \qquad f(R_1)\cdot f(R_2|R_1,R^*)\cdot\int_{\delta_{0*}}^{\delta_0^*} f(\delta_0|R_1)d\delta_0$$

$$f(R_1)\cdot f(R_2|R_1)\cdot\int_{\delta_0^*}^{\infty} f(\delta_0|R_1,R_2)d\delta_0 \ .$$ [1]

The middle term is somewhat asymmetric with the other two because if $\delta_{0*} < \delta_0 < \delta_0^*$, $R_2 = R^* + \varepsilon_2$ and the conditional density $f(\delta_0|\cdot)$ does not depend on ε_2 since η and ε are assumed independent.[2]

Now we simply need to realize that R_2 will only be observed if the person moves. That is for any of the possible ways that R_1 and R_2 could be observed as described in equation (18), we must realize that each possi-

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1. To find δ_{0*}, we solve implicitly for the values of R_* and δ_{0*} that sustain the equality $V(Y+P,R^*;\delta_{0*}) =$

$$= (Y+P-R^*)^{1-\delta_{0*}(Y+P)^{\delta_1}}(R^*)^{\delta_{0*}(Y+P)^{\delta_1}} =$$

$$= (Y-R_*)^{1-\delta_{0*}Y^{\delta_1}}(R_*)^{\delta_{0*}Y^{\delta_1}} = V(Y,R_*;\delta_{0*}) \ .$$

The appropriate values of R_* and δ_{0*} must be determined at each iteration of the maximum likelihood process, because δ_1 is a parameter determined by the maximization and because P is allowed to enter the exponent in evaluating $V(Y+P,R^*;\delta_{0*})$, unlike the specification in Hausman and Wise [1980].

2. Possibly it is clearer in this instance to use $f(\varepsilon_2|R_1)$ instead of $f(R_2|R_1,R^*)$.

bility without transaction costs would be observed only if, in addition, g were greater than zero. If we let $\Phi[\cdot]$ be shorthand for $\Pr[g > 0|\delta_0,R_1,R_2]$, we can write the probability P_1 of moving and observing R_2 versus the probability P_2 of not moving as

$$P_1 = f(R_1)\cdot f(R_2|R_1)\cdot\int_{-\infty}^{\delta_{0*}} f(\delta_0|R_1,R_2)\Phi[\cdot]d\delta_0$$

$$+ f(R_1)\cdot f(R_2|R_1,R^*)\cdot\int_{\delta_{0*}}^{\delta_0^*} f(\delta_0|R_1)\cdot\Phi[\cdot]d\delta_0$$

$$+ f(R_1)\cdot f(R_2|R_1)\cdot\int_{\delta_0^*}^{\infty} f(\delta_0|R_1,R_2)\cdot\Phi[\cdot]d\delta_0 ,$$

(18)

$$P_2 = f(R_1)\cdot\int_{R_2} f(R_2|R_1)\cdot\int_{-\infty}^{\delta_{0*}} f(\delta_0|R_1,R_2)\{1-\Phi[\cdot]\}d\delta_0 dR_2$$

$$+ f(R_1)\cdot\int_{R_2} f(R_2|R_1,R^*)\cdot\int_{\delta_{0*}}^{\delta_0^*} f(\delta_0|R_1)\{1-\Phi[\cdot]\}d\delta_0 dR_2$$

$$+ f(R_1)\cdot\int_{R_2} f(R_2|R_1)\cdot\int_{\delta_0^*}^{\infty} f(\delta_0|R_1,R_2)\{1-\Phi[\cdot]\}d\delta_0 dR_2 .$$

Again, some further details are provided in Appendix A.

II. PARAMETER ESTIMATES

Our parameter estimates are based on samples of low-income families in Allegheny County, Pennsylvania (Pittsburgh) and Maricopa County, Arizona (Phoenix) who were surveyed as part of the housing allowance demand experiment. To be eligible for the experiment, family income was limited to \$12,750 in Phoenix and \$9,150 in Pittsburgh.[1] Only renters were included. Families determined to be eligible for the experiment were randomly assigned to a control group or to one of several experimental treatment groups. Then the families were offered enrollment in the program. Those enrolled were surveyed periodically from the Spring of 1973 to the Winter of 1977. Our estimates pertain to data at the time of enrollment (period 1) and two years later (period 2). As mentioned above, most of our estimates are based on the control group, but we have also obtained estimates based on the minimum rent treatment group combined with the lump sum transfer group.

Parameter estimates for both cities combined are shown in Table 1. The first four columns present alternative models for controls distinguished by different specifications of the disturbance structure. The last column shows estimates for the treatment group. The parameter estimates for controls are not sensitive to the error specification. Thus we shall discuss first the differences among the disturbance term specifications and then in discussing the remaining parameter estimates we shall refer only to those in column four.

The first two specifications allow for no taste variation, that is η is assumed equal to zero. In this case, the maximization errors in the two periods are allowed to be correlated. The correlation is about .16,

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1. The difference apparently arises primarily because the cost of "modal" housing is less in Pittsburgh than in Phoenix (see the footnote to Table 4) and thus the income limit was lower in Pittsburgh.

Table 1. Parameter Estimates (and Asymptotic Standard Errors)

Variable[a]	Controls				Minimum Rent and Lump Sum Treatment Group
	(1)	(2)	(3)	(4)	
Income Effect, δ_1	-.747 (.026)	-.750 (.027)	-.734 (.027)	-.739 (.027)	-.696 (.039)
Determinants of δ_0:					
Constant	.492 (.060)	.508 (.062)	.479 (.062)	.499 (.063)	.593 (.075)
Family Size	.025 (.006)	.026 (.006)	.026 (.006)	.026 (.006)	.014 (.008)
Age 62 Years Plus	-.074 (.033)	-.067 (.034)	-.068 (.033)	-.064 (.034)	-.051 (.037)
Non-white	-.115 (.024)	-.117 (.024)	-.114 (.025)	-.115 (.025)	-.112 (.031)
Phoenix	.173 (.020)	.173 (.021)	.164 (.021)	.164 (.021)	.107 (.026)
Female Head	.088 (.021)	.088 (.021)	.089 (.021)	.088 (.022)	.104 (.023)
Education of Head	.020 (.003)	.021 (.003)	.020 (.003)	.020 (.004)	.013 (.004)
Transaction costs (ln m)	.138 (.050)	.135 (.050)	.142 (.050)	.141 (.050)	.116 (.056)
Variance of Rent σ_ε^2	.170 (.006)	.172 (.007)	.134 (.009)	.134 (.009)	.127 (.008)
Variance of δ_0, σ_η^2	--	--	.016 (.004)	.017 (.004)	.014 (.004)
Correlation of ε's, ρ_ε	.158 (.050)	.164 (.051)	--	--	--
Disequilibrium First Period, α	--	-.037 (.027)	--	-.036 (.026)	-.052 (.033)

Table 1. Parameter Estimates (and Asymptotic Standard Errors)

Variable[a]	Controls				Minimum Rent and Lump Sum Treatment Group
	(1)	(2)	(3)	(4)	
Sample Size	655	655	655	655	527
Log-Likelihood	-943.07	-941.94	-936.96	-935.90	-739.04

a. Rent and income are measured in 100's.

suggesting that only about sixteen percent of the error variance in rent could be accounted for by family-specific components of variance. The second specification allows for a disequilibrium component of the first-period error term. It is estimated to be negative, suggesting that on average families were spending somewhat less than the rent that would have been preferred if moving were costless. The next two specifications allow for a family-specific taste parameter η. Consider column four. The variance of ε is estimated to be .134 which yields a standard deviation of \$36.60 in dollar units. This may be compared with a mean rent of \$126 in period 2. The variance of η is estimated to be .017, corresponding to a standard deviation of .13. It may be compared to the estimated average δ_0 of .86. Recall that η appears in $\delta_0 = X\delta + \eta$, where the proportion of income allocated to rent is $\delta_0 Y^{\delta_1}$. Again, the estimated first period disequilibrium term is negative. We shall now consider the other parameter estimates in column four.

First, the transaction costs parameter is estimated to have a mean of .141. This means that on average the gain from a reallocation of income between housing and other things would have to provide a 14 percent increase in utility to induce the average family to move. Another way to interpret the estimate is that the average family would be indifferent between moving and a \$60 per month increase in income, the income equivalent of a 14 percent change in utility. We shall see below that many treatment families passed up payments of this size that were available had they increased expenditure on housing.[1]

1. Allen, Fitts, and Glatt [1981] report that many experimental treatment families who did not increase rent enough to receive payments even though they could have done so "and would have had at least \$480 a year of allowance dollars left over . . . "

Next, the income effect δ_1 is estimated to be -.739. This corresponds to an elasticity of rent with respect to income of .26. This estimate is within the range of estimates of other investigators based on microdata, although on the low side.[1] Our estimates pertain to renters and thus might be expected to be relatively low. In addition, our estimates pertain to low-income families only. And among low-income families, those with higher incomes who might be expected to spend more on housing may disproportionately be homeowners--and thus not in the sample--although we have no evidence that this is true.[2] Finally, our estimates pertain to only two metropolitan areas and elasticities may vary substantially among geographic areas.[3] Indeed, we shall show below that the estimated values in our two cities are very different. Other evidence is consistent with broad varia-

1. See Mayo [1981] for a survey of recent results. Estimates with a correction for permanent versus transitory income are usually a bit higher than those based on current income; most are in the range of 0.3 to 0.5 for renters. It is not clear, however, which concept is the most appropriate for predicting the effect of government transfer programs. We shall address this issue in part by checking estimates based on our model with the observed experimental transfer payment treatment effects. These, of course, could not be considered permanent in the experimental context but they were guaranteed for three years. Finally, our estimates of course pertain to rents that families choose when they overcome moving transaction costs to change rent. Estimates for owners, and for renters based on aggregate data are usually higher than ours. See for example de Leeuw [1971], King [1980], and Rosen [1979].

2. Aaron [1981] reports that data from the Seattle-Denver Income Maintenance Experiment indicate that 4.5 to 10.6 cents out of each assistance dollar goes for housing. These data pertain to both renters and homeowners. Our estimates indicate that on average about 6 cents of each additional dollar of income would go for housing.

3. Consistent with our results, however, are those from the supply experiment component of the Experimental Housing Allowance Program, conducted in Brown County, Wisconsin (including Green Bay) and St. Joseph County, Indiana (including South Bend). It was found in these locations that providing allowances to all eligible families had almost no effect on the housing market--prices in particular--simply because income elasticities were so low that the allowances created almost no increase in housing demand.

tion among individuals. For example, King [1980] estimated that price elasticities varied widely among individuals, although his specification did not allow for random income elasticities across individuals.

To check that our estimates are not due to a functional form misspecification, we have graphed in Figure 3 the predicted values of the proportion of income spent on rent together with the observed values. For completeness, we have also included in Figures 4 and 5 analogous graphs for Pittsburgh and Phoenix separately, with the corresponding estimates to be discussed below. The graphs shown pertain to rent in period 1.[1] It should be clear from the graphs that the predicted relationship virtually matches the observed one. Indeed, even directions of movement in the underlying shape of the relationship, that result from differences in the X values that determine δ_0, are picked up by the specification.

Finally, we consider briefly the coefficients on the variables that determine δ_0. The average estimated value of δ_0 is .86. We estimated that δ_0 is .115 lower for non-whites than for whites and .088 higher for female-headed households. Possibly these latter families devote a greater proportion of their income to housing because female heads are less likely than male heads to be working and thus have smaller work expenses. Non-whites may spend less than whites due to different preferences or because of disporportionate constraints on housing purchase opportunities versus opportunities for purchasing other goods. We also find that the more educated devote more of their income to rent and that rent increases with family size, as expected. Finally, we see that families devote a substantially greater proportion of their incomes to housing in Phoenix than in

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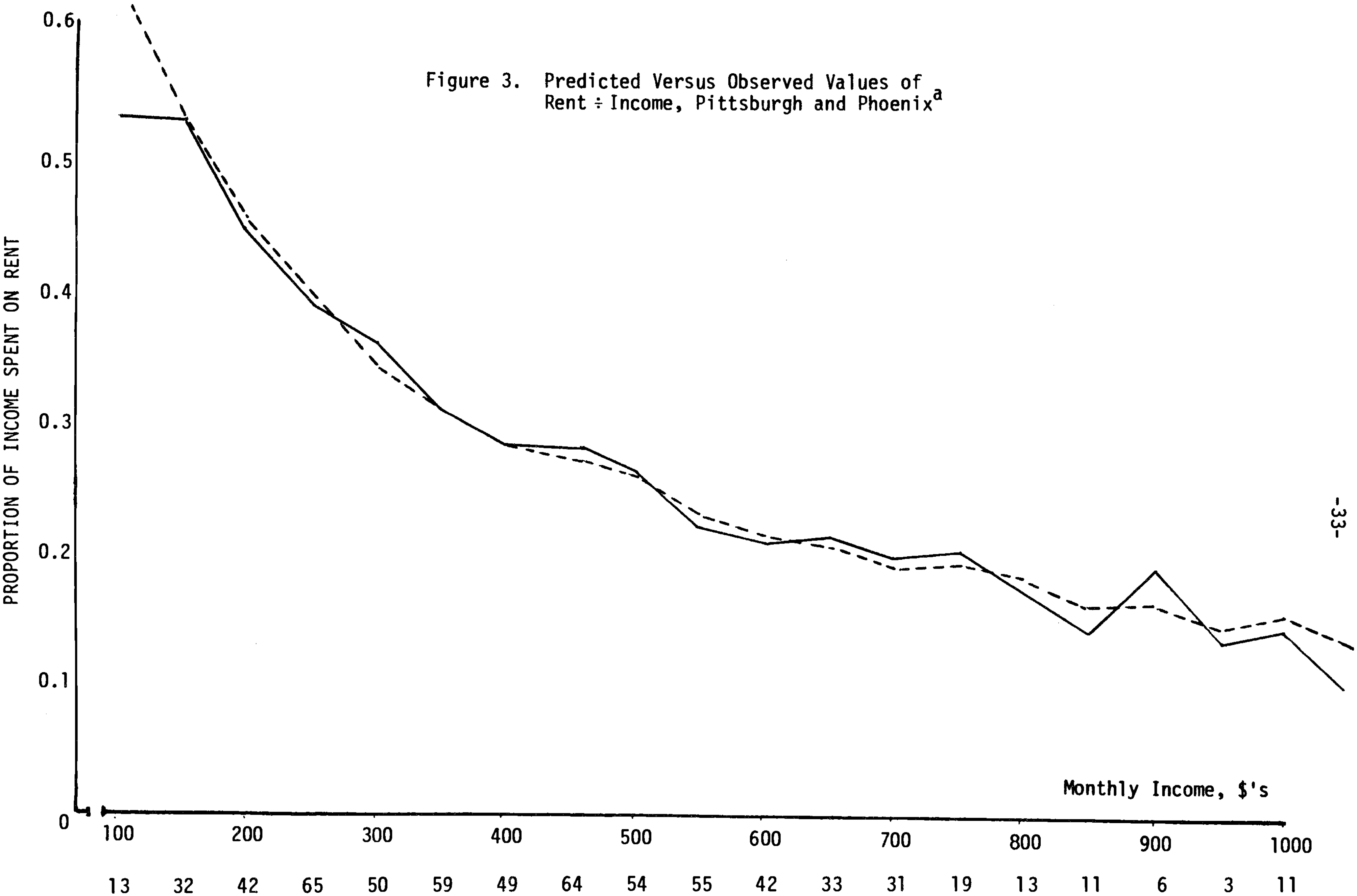
1. Comparable graphs for rent in period 2 conditional on moving have the same appearance as those shown and are not presented here.

Pittsburgh; δ_0 is .164 higher in Phoenix. This observation, as well as summary data, suggest that the relationship between income and rent may be quite different in the two cities, possibly in more general ways than can be captured by a single shift parameter. We present below more detailed estimates of the differences.

But first we consider the estimates in the last column of Table 1. These estimates are based on the experimental treatment group who faced the discontinuous budget constraint created by the minimum rent plan. (Actually about 20 percent of the group faced an unconstrained lump sum transfer.) These estimates were obtained using the procedure outlined in Section I.3.3 above. We observe only that the estimates based on this group are very close to those obtained using the control sample. For example, the transaction costs parameter is about .12 for these data versus .14 for the control group data, while the income elasticity $(1 + \hat{\delta}_1)$ is about .30 for the treatment group versus .26 for the control group. This provides some evidence that our specification is robust against this type of alteration in the budget constraint. Quite different results could be obtained of course if our rent function and corresponding preference function were incorrectly specified to a substantial degree. These results also suggest that our model may predict well the changes in response when families are faced with the non-linear budget constraint, as in the treatment plan. We shall return below to additional external tests of the model.

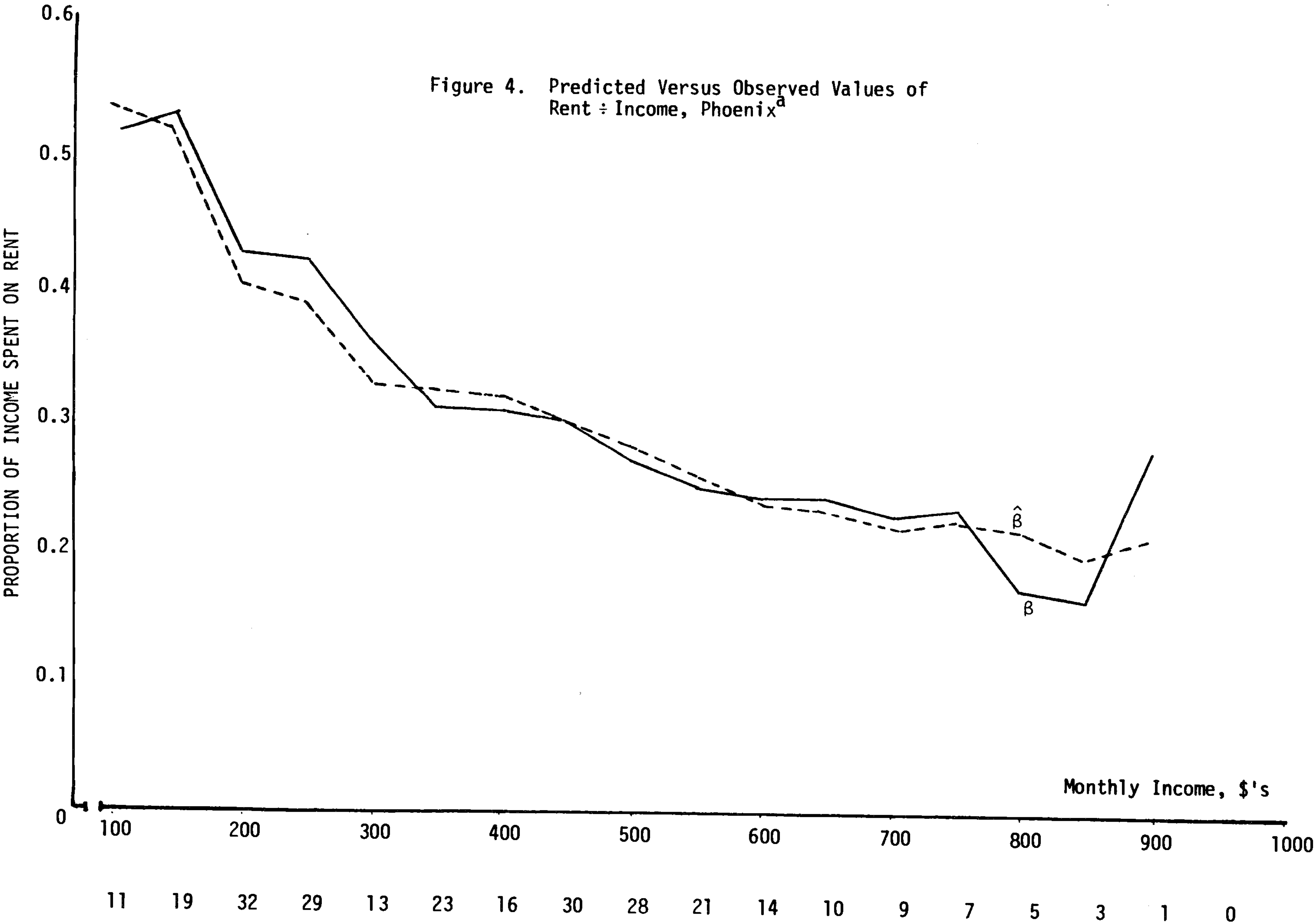
We now consider estimates for Pittsburgh and Phoenix separately, that are presented in Table 2. The specification underlying these results is the same as model 4 in Table 1. First we observe that the income elasticity is much lower in Pittsburgh than in Phoenix--.13 versus .32. The graphs in

Figure 3. Predicted Versus Observed Values of Rent ÷ Income, Pittsburgh and Phoenix[a]



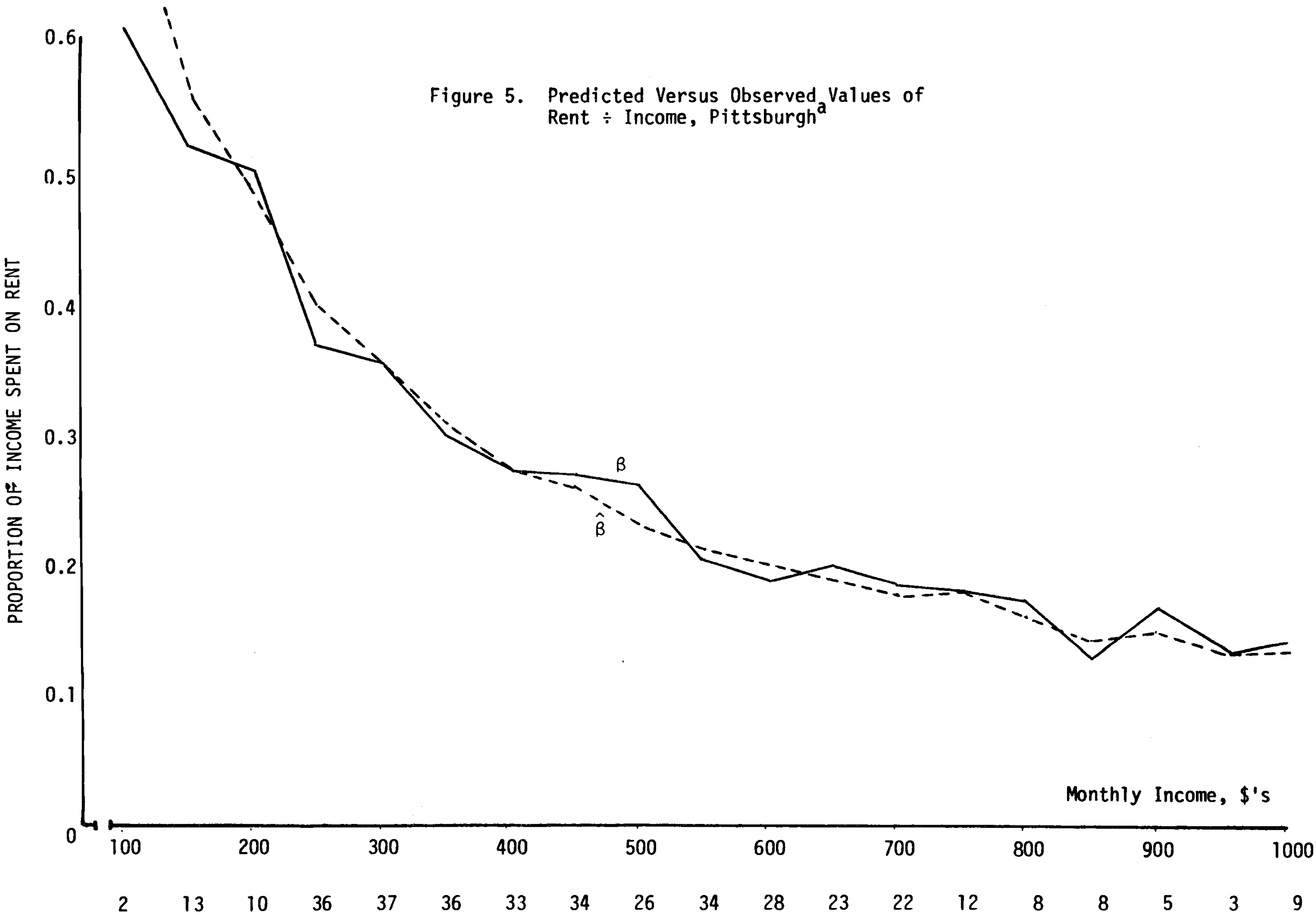
a. The numbers below the income values represent the number of observations in the corresponding income interval. For example, there are 42 observations in the interval $175 to $225.

Figure 4. Predicted Versus Observed Values of Rent ÷ Income, Phoenix[a]



a. The numbers below the income values represent the number of observations in the corresponding income interval. For example, there are 32 observations in the interval $175 to $225.

Figure 5. Predicted Versus Observed Values of Rent ÷ Income, Pittsburgh[a]



a. The numbers below the income values represent the number of observations in the corresponding income interval. For example, there are 10 observations in the interval $175 to $225.

Figures 4 and 5 give a detailed picture of the relationships between income and rent in the two cities and verify the accuracy of the general specification for each city.[1] Consistent with the differences in the income elasticities we observe large differences in the transaction costs parameters; the mean is not significantly different from zero in Phoenix, while it is .27 in Pittsburgh. Summary statistics show families are 30 percent more likely to move in Phoenix than in Pittsburgh. In addition, the estimated disequilibrium parameter is relatively large and negative in Phoenix, suggesting that families there were on average spending $12 per month less on rent than the preferred levels, while in Pittsburgh, families were on average spending $6 per month more than the preferred level. Other than observing that these differences are consistent with summary statistics we can only speculate about possible reasons for the differences. Based on vacancy rates, the housing market was tighter in Pittsburgh than in Phoenix during this period.[2] Most minority families in the Pittsburgh sample were Black while those in Phoenix were Mexican-American. Possibly cultural differences between the two groups lead to different rent patterns. For whites or non-whites it may be that cultural attachment to local communities is stronger in Pittsburgh than in Phoenix, and for many larger housing expenditure would require leaving the community. There may also be differences between cities in the rates at which rents of occupied housing are raised; such increases are usually found to be lower than when tenants change.

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1. Cronin [1981] reports the elasticity estimates of several authors based on these data. Most are not very different from ours. Those of Cronin and of Hanushek and Quigley are quite close to ours. Our estimates at least for Phoenix are slightly higher than those of these authors, possibly because our estimates presumably pertain to "preferred" rent levels.

2. During the experiment, the vacancy rate in Phoenix was more than double the rate in Pittsburgh. (See Kennedy [1980], p. A-10.)

Table 2. Parameter Estimates (and Asymptotic Standard Errors for Pittsburgh and Phoenix Separately)

Variable	Phoenix	Pittsburgh
Income Effect, δ_1	-.680 (.030)	-.872 (.047)
Determinants of δ_0:		
Constant	.684 (.078)	.425 (.105)
Family Size	.024 (.008)	.049 (.012)
Age 62 Years Plus	-.172 (.046)	.074 (.060)
Non-White	-.142 (.034)	-.101 (.040)
Female Head	.071 (.027)	.094 (.040)
Education of Head	.020 (.004)	.030 (.007)
Transactions Cost (ln m)	-.026 (.076)	.267 (.067)
Variance of Rent σ_ε^2	.116 (.011)	.137 (.015)
Variance of δ_0, σ_η^2	.013 (.005)	.023 (.009)
Disequilibrum First Period, α	-.124 (.036)	.065 (.041)
Sample Size	276	380
Log-Likelihood	-379.7	-530.8

dollar cost of moving may also differ between the cities.[1]

We also observe that rents are lower for older than younger persons in Phoenix, but that this is not true in Pittsburgh. This seems consistent with higher moving transaction costs in Pittsburgh than in Phoenix. The other coefficients determining δ_0 are similar in the two cities.

III. PREDICTIONS AND COMPARISON WITH EXPERIMENTAL RESULTS

To get an idea of the predictive validity of the model, we used our estimates based on the control sample to predict the outcomes under the experimental minimum rent treatment plans for families who were assigned to the treatment group. Our predictions together with the observed experimental outcomes are shown in Table 3. We shall emphasize presently that this comparison does not provide an unambiguous test of the model, but first we point to the primary features of the comparison. In both cities, the predicted dollar rent figures are very close to the observed ones, both on average and for subgroups (e.g., persons who move, persons who participate--$R_2 > R^*$, and persons whose period 1 rent was below R^*). Notice also that the difference between the rent of movers and non-movers is much greater in Phoenix than in Pittsburgh. This is observed in the experimental data and also is captured by our model. This result of course is consistent with the differences in the estimated disequilibrium terms in the two cities -\$12 in Phoenix versus +\$6 in Pittsburgh--as well as the lower income elasticity in Pittsburgh.[2]

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1. Weinberg, Friedman, and Mayo [1981] report average "out-of-pocket" moving costs of \$54.06 in Pittsburgh and \$12.59 in Phoenix. They also report a "mean search time" of 95 days in Pittsburgh and 33 days in Phoenix, based on baseline interviews.

2. In general, the experimental treatments had much less effect in Pittsburgh than in Phoenix. Consistent with this finding and with our estimate of much higher transaction costs in Pittsburgh, Straszheim [1981] reports results of Kennedy and MacMillan indicating that while the payment level was significantly related to participation for enrollees with $R_1 < R^*$ in Phoenix it was not significant and indeed negatively related to participation in Pittsburgh, based on coefficients in a logit model.

Table 3. Predicted Versus Observed Experimental Outcomes for the Minimum Rent Treatment Group, by City[a]

Outcome	Pittsburgh		Phoenix	
	Observed	Predicted[b]	Observed	Predicted[b]
Rent-Average	\$120	118	\$147	141
Proportion Who Move	.41	.39	.65	.54
Rent-Movers	\$124	121	\$162	154
Rent-Nonmovers	\$116	116	\$120	125
Proportion Who Participate	.59	.53	.58	.50
Rent-Participants	\$142	141	\$176	179
Rent-Nonparticipants	\$88	91	\$107	102
Proportion Who Move $\mid R_1<R^*$	.40	.40	.68	.55
Proportion Who Move $\mid R_1>R^*$	.42	.38	.58	.51
Proportion Participants $\mid R_1<R^*$	.32	.22	.40	.31
Proportion Participants $\mid R_1>R^*$	.89	.88	.96	.89
Rent $\mid R_1<R^*$	\$110	106	\$137	129
Rent $\mid R_1>R^*$	\$131	131	\$168	164

a. All rent outcomes pertain to period two. For example, Rent $\mid R_1<R^*$ is the average rent in period two under the treatment program, given that initial rent R_1 was less than the minimum R^*.

b. Simulated results obtained first by using our estimated model based on controls to predict the outcomes for each family in the experimental treatment group and then aggregating over the individual predictions. The procedure is described in Appendix B.

The differences between the predicted and the observed outcomes are primarily in the proportion of families that moves and in the proportion that participates (have rents greater than R^*). Note that many families must move in order to qualify for the experimental payment. It seems apparent that a very likely explanation for the difference lies in the selection procedure that generated the experimental and control samples.

First a random sample of families who were eligible for the experiment--whose incomes controlling for family size were low enough--were assigned randomly to the control group or to a treatment group. After this assignment, those who were eligible were offered enrollment in the experiment. Many did not enroll. Under this procedure, it is easy to see that persons who thought that they would not benefit from the program, would be least likely to enroll. In particular, families with rents below R^* and who would probably have to move to receive the program subsidy would be less likely to enroll. That is, persons who didn't want to move and thus wouldn't participate would be less likely to enroll. Consistent with this observation is the finding that families were less likely to enroll in Pittsburgh (where our estimated moving transactions cost is high). Also persons who hadn't moved recently and presumably had a greater aversion to moving were less likely to enroll. And very low-income families who would probably have rents well below R^* and thus likely not to want to increase their rents enough to benefit from the experiment, were also less likely to enroll. So were high income families whose program payments would be small.[1] In general, it appears that those in the eligible treatment group who knew they didn't want to move and thus would not benefit from the program were

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1. See Straszheim [1981], p. 124 and 126.

less likely to enroll. These factors are much less likely to have a systematic effect on enrollment in the control group since there is no payment that is conditional on moving.

It is also important to realize that the experimental data pertain only to families who enrolled and were in the sample both at the time of enrollment and two years later. Of families who enrolled in the minimum rent plans, 36 percent had dropped out of the experiment two years later. Among controls 37 percent dropped out.[1] It is likely, however, that dropping out was much more systematically related to moving--and thus receipt of the program subsidy--among the treatment group than among the control group. Thus persons who are unlikely to move are disproportionately excluded from the treatment group but not from the control group. This would lead to greater observed moving among persons who enrolled in the treatment group and remained for two years.[2]

We are able to make at least one crude correction of the observed experimental participation rate. Suppose that we consider all those eligible for enrollment as the relevant sample and assume that none of those who would participate declined enrollment. Then the estimated participation rates are .51 for Pittsburgh and .52 for Phoenix, very close to our predicted participation rates.[3]

In short, it appears that our predictions match the experimental results very closely and that where the two differ our estimates are quite possibly more accurate population estimates than are the experimental estimates.

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1. See Allen, Fitts, and Glatt [1981], p. 8.

2. Note that the fact that we are able to predict quite well the rate of the treatment group movers tends to suggest that moving transaction costs and taste for housing are not highly correlated, and thus the predictions tend to support the assumption that η and M are independent.

3. These calculations are based on enrollment and participation rates given in Straszheim [1981], p. 122.

IV. SIMULATIONS OF PROGRAM EFFECTS

To provide illustrative estimates of the deadweight loss associated with minimum rent subsidy plans, we have simulated the effects on the control group of two representative minimum rent plans and have calculated the concomitant deadweight loss. For comparison, we have also presented simulated effects under an unconstrained lump-sum transfer program. The results are shown in Tables 4 through 6. Both plans base the transfer payment P on family income and the cost of "modal" housing which varies with family size and between the two cities. The first plan is relatively generous. It provides a payment that makes up the difference between 1.2 times modal housing cost and 25 percent of income; and sets a relatively low minimum rent, at .7 times the cost of modal housing. The second plan only makes up the difference between 25 percent of income and .8 times the cost of modal housing, and sets a higher minimum rent at .9 times the cost of modal housing. The plans are representative of those tested in the experiment and are also similar to the types of plan that are the subject of current discussion.

The primary effects of the plans are shown in Table 4, with no plan at all taken as the base for comparison. In general, the effects of the plans are very small in Pittsburgh but have modest effects in Phoenix.[1] In both cities the effect of the minimum rent plan is greater than the effect of the lump-sum program. Under the more generous plan in Phoenix average rent is 8 percent higher under minimum rent than under no plan

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1. In some cases, small effects in Pittsburgh are not apparent because of rounding.

Table 4. Simulated Effects of Two Minimum Rent and Lump-Sum Housing Subsidy Plans on Control Group, by City and Plan[a]

Effect	Phoenix			Pittsburgh		
	No Program	Minimum Rent	Unconstrained Lump-Sum	No Program	Minimum Rent	Unconstrained Lump-Sum
$P = 1.2$(Modal Housing Cost) $- 0.25(Y)$; $R^{*} = 0.7$(Modal Housing Cost)[b]						
Average P Offered	--	\$115	\$115	--	\$57	\$57
Proportion Who Participate	--	0.64	1.00	--	0.69	1.00
Proportion Who Move	0.51	0.56	0.51	0.39	0.39	0.39
Average Rent, R_2	\$136	\$147	\$143	\$121	\$124	\$121
Average P to Participants	--	\$101	\$115	--	\$52	\$57
Proportion Participating $\vert R_1<R^*$	--	0.42	1.00	--	0.28	1.00
Average $R_1 \vert R_1<R^*$	\$98	\$98	\$98	\$90	\$90	\$90
Average $R_2 \vert R_1<R^*$	\$111	\$126	\$119	\$97	\$102	\$98
$P = 0.8$(Modal Housing Cost) $- 0.25(Y)$; $R^{*} = 0.9$(Modal Housing Cost)[b]						
Average P Offered	--	\$48	\$48	--	\$18	\$18
Proportion Who Participate	--	0.43	1.00	--	0.40	1.00
Proportion Who Move	0.51	0.53	0.51	0.39	0.39	0.39
Average Rent, R_2	\$136	\$147	\$139	\$121	\$123	\$121
Average P to Participants	--	\$37	\$48	--	\$17	\$18
Proportion Participating $\vert R_1<R^*$	--	0.29	1.00	--	0.17	1.00
Average $R_1 \vert R_1<R^*$	\$110	\$110	\$110	\$103	\$103	\$103
Average $R_2 \vert R_1<R^*$	\$121	\$135	\$125	\$106	\$110	\$107

a. Because of rounding, some entries may show no change across programs when in fact the simulations indicate a small change.

b. Applies with minimum rent plan. The average modal housing cost is \$189 in Phoenix and \$147 in Pittsburgh.

and 5 percent higher under the lump-sum plan. There is essentially no effect from the lump-sum plan in Pittsburgh but the minimum rent plan increases rent by about 2.5 percent. Under the lump-sum plan of course, every family gets a grant. We see also that the participation rate is substantially higher in Phoenix than in Pittsburgh, reflecting the lower transaction costs and higher income elasticities in Phoenix. Under the minimum rent plans, the largest effect is on families with initial rent R_1 less than the minimum R^*. For example, the effect in Phoenix under the more generous plan is $15 or 13.6 percent (over no program) for this group compared with $11 or 8 percent for all families. In Pittsburgh, the increase is about 5 percent for families with $R_1<R^*$. Further comparisons can be made by considering the numbers in the table.

Because families with $R_1<R^*$ are presumably especially targeted under the minimum rent plan, we present in Table 5, some additional calculations for those members of this group who participate in the program by increasing rent R_2 to at least R^*. In particular, there is a potential deadweight loss associated with payments to this group and we present estimates of its magnitude. For persons with $R_1>R^*$, the minimum rent plan is equivalent to a lump-sum transfer scheme and there is no deadweight loss associated with the transfer.

The deadweight loss figures are calculated as follows. (1) First, we calculate for each family the preference level reached under the minimum rent plan and the associated payment P.[1] (2) Then we calculate the preference

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1. Note that our simulation procedure makes this outcome stochastic. For example, our stochastic specification yields some families with attributes X who move and receive the payment P and others who don't. Some details are provided in Appendix B.

Table 5. Simulated Effects of the Minimum Rent Plans on Control Group Families with $R_1 < R^*$ but $R_2 \geq R^*$, by City and Plan

Effect	Phoenix	Pittsburgh
$P - 1.2(\text{Modal Housing Cost}) - 0.25(Y)$ $R^* = 0.7(\text{Modal Housing Cost})^a$		
Proportion of All Eligibles	0.24	0.10
Average R_1	\$99	\$89
Average R_2	\$171	\$137
Average P	\$140	\$83
Average DWL (\$'s)	\$21	\$11
Average DWL÷P	0.13	0.13
ΣDWL÷ΣP	0.15	0.16
$P = 0.8(\text{Modal Housing Cost}) - 0.25(Y)$ $R^* = 0.9(\text{Modal Housing Cost})^a$		
Percent of All Eligibles	0.19	0.09
Average R_1	\$111	\$98
Average R_2	\$203	\$160
Average P	\$71	\$37
Average DWL (\$'s)	\$23	\$11
Average DWL÷P	0.29	0.35
ΣDWL÷ΣP	0.32	0.31

a. Applies with minimum rent plan. The average modal housing cost is \$189 in Phoenix and \$147 in Pittsburgh.

level that these families would obtain with lump-sum transfers equal to these same P values. (3) Finally, we calculate the income $\tilde{P}$ that could have been subtracted from the levels of P in (2) to bring individuals to the level of utility in (1).[1] The excess burden is taken to be $\tilde{P}$.

For families with $R_1<R^*$. we find that deadweight loss is about 15 percent of total payments under the more generous plan and more than 30 percent of payments under the less generous plan. The average payment is approximately twice as high under the more generous plan in both cities, but we can see from table 4 that relative to no plan the average rent increase for persons with $R_1<R^*$ is about the same under both plans. The explanation for the increment, however, differs between the plans. We shall detail the difference for Phoenix. Fewer families obtain payments under the less generous plan, but those who do increase their rents much more to obtain them. Persons who move and receive payments under the less generous plan increase their rents over R_1 by \$92 on average while under the more generous plan the average increase is only \$72. This is because the R^* value is higher under the less generous plan. However, only 29 percent of those with $R_1<R^*$ receive payments under the less generous plan while 42 percent of this group receive payments under the more generous plan, as shown in Table 4. In either case, the deadweight loss is relatively low because most targeted families don't participate in the program. Many of those who do would have moved even without the potential incentive provided

1. We have also calculated the income increases $\tilde{P}$ that would have to be added to the levels of P in (1) to bring individuals to the level of utility in (2); the results were virtually the same in both methods.

by the plan.[1] Those who move are most likely to be those with low moving transaction costs, otherwise they would not move as we shall show by example below. This means that the deadweight loss associated with the program results largely from the non-optimal allocation of expenditures between housing and other goods.

By considering an illustrative example, we can see that persons with even average transaction costs would be unlikely to move only to receive the payment. For this purpose we shall use the average estimates for the two cities combined reported in column 4 of Table 1 and we shall make use of the graph that is drawn to scale and shown in Figure 6. The figure depicts the situation of a family with income slightly less than the sample average that faces a minimum rent of $180, approximately equal to the less generous plan value in Phoenix, and that faces a payment of $50. Suppose that this family has the average δ_0 = .86 and has initial rent R_1 = $124. If transaction costs were zero, this family would be better off moving and increasing its rent by $56 and receiving the $50 payment (point B). But with moving transaction costs equal to the average, the initial position is slightly preferred to point B, as shown by the ratios below the graph. Families with higher transaction costs would find the change even less desirable.[2] If this family were to receive a lump-sum grant of $50 it would maintain the same rent of $124 and use the $50 to purchase other goods, point C. The alloca-

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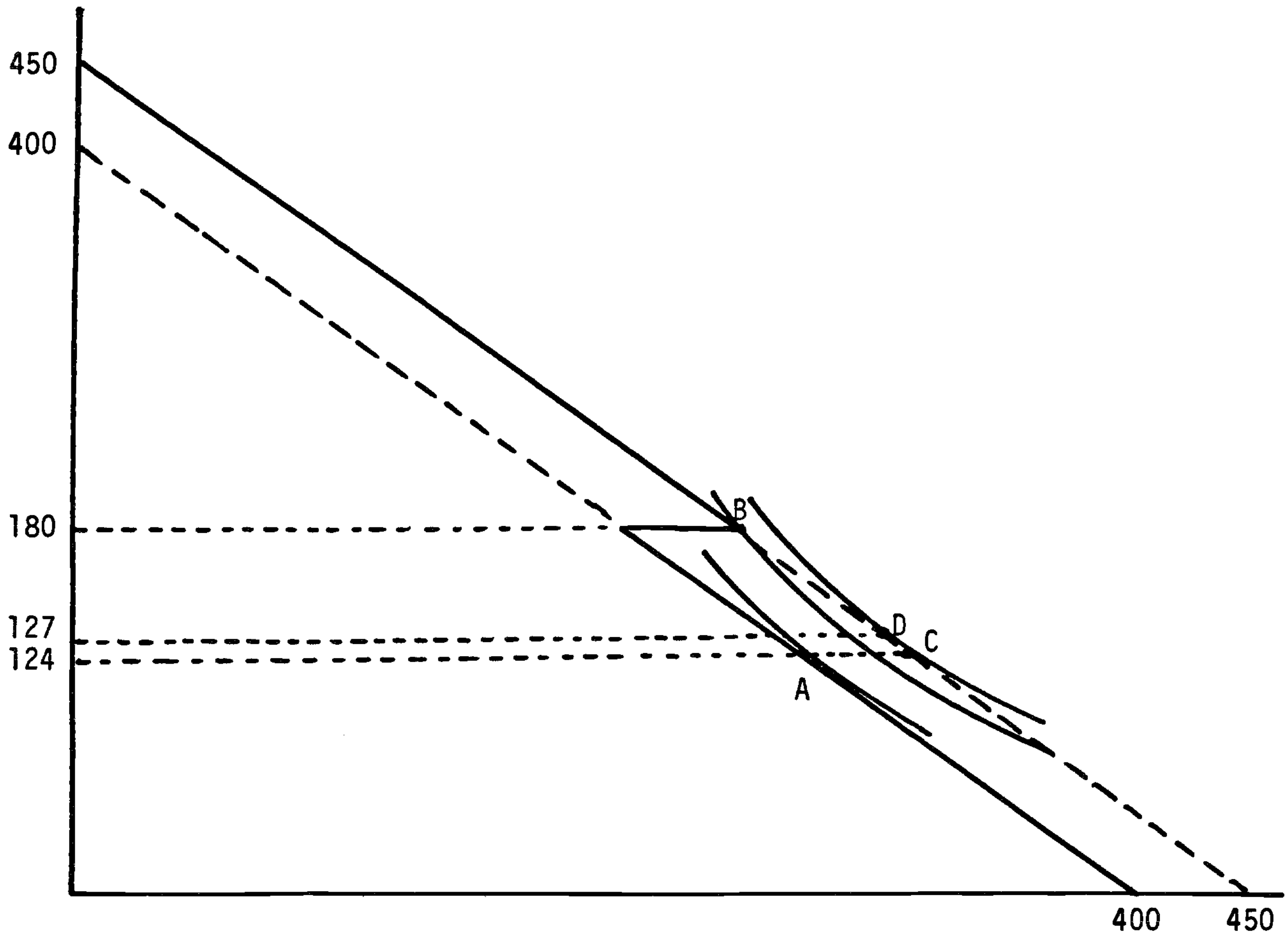
1. We can see this by noting that if we assumed no increase in spending without a program, we would calculate the plan effect in the less generous case for example as the average rent increase of participants ($92) times the proportion who participate (.29), given $46.68. However, we can see from Table 4 that the increase over no plan is only $14 ($135-$121).

2. Another way to evaluate the effect of transaction costs is to consider changes in the probability of moving with changes in the mean value of M. With the estimated mean value the probability of moving from A to B would be .544, while the probability would be .488 if the mean were zero. Thus this increase in mean transaction costs reduces the probability of moving by 10.3 percent.

Figure 6. Illustration of the Effect of Transactions Costs on Program Participation[a]



$Y = 400$

$P = 50$

$R^* = 180$

$M = 1.15$

$\delta_0 = .86$

$U(B)/U(A) = 1.12 > 1$

$U(B)/[U(A)\cdot M] = 0.97 < 1$

$U(C)/U(A) = 1.15 > 1$

$U(D)/U(C) = 1.00 = 1$

$U(D)/[U(C)\cdot M] = 0.87 < 1$

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a. Only the utility rankings of budget allocations A through D are unaffected by our choice of a utility index. However, for illustrative purposes we have calculated utility levels using the functional form described above to determine whether the ratios of utilities are greater or less than unity.

tion at C is essentially as good as point D and if to obtain D the family has to surmount the moving transaction costs, C is much preferred to moving to obtain the slight reallocation of expenditure as at point D.

To return to our main theme, we note that while the welfare gain to eligibles under the lump-sum program is much higher than under the minimum rent plan--the average payment is much higher--neither plan is in general a very effective way of increasing housing expenditure, presumably an important feature of the plans for those whose goal it is to increase such expenditure. The relevant numbers are shown in Table 6. The lump-sum plans increase rent by about 6 cents per dollar of payment in Phoenix and only 2 cents in Pittsburgh. The more generous minimum rent plan leads to a 17 cent increase per dollar of payment in Phoenix and 8 cents in Pittsburgh. The much lower payments under the less generous minimum rent plan yield much larger rent increases per payment dollar--68 cents and 41 cents respectively in Phoenix and Pittsburgh. The reason that the more generous plan is so costly in this sense is that a large share of payments go to families who have initial rent above R^* and who don't increase rent much when payments are received.

In short, the minimum rent plan discourages most eligibles with $R_1 < R^*$ from participating and receiving payments. Thus the excess burden proportions are relatively low because most relevant eligibles receive no payments at all. In addition, persons who do move and receive payments tend to be among those with the lowest transaction costs; otherwise they wouldn't move.

V. CONCLUSIONS

We have set out to analyze the effects of moving transaction costs and

Table 6. Simulated Average Payments and Rent Increases by City and Plan

Effect	Phoenix		Pittsburgh	
	Minimum Rent	Unconstrained Lump-Sum	Minimum Rent	Unconstrained Lump-Sum
$P = 1.2(\text{Modal Housing Cost}) - 0.25(Y)$; $R^* = 0.7(\text{Modal Housing Cost})$[a]				
Average Payment	\$66	\$115	\$36	\$57
Average Rent Increase	\$11	\$7	\$3	\$1
Average Rent Increase ÷ Average Payment	0.17	0.06	0.08	0.02
$P = 0.8(\text{Modal Housing Cost}) - 0.25(Y)$; $R^* = 0.9(\text{Modal Housing Cost})$[a]				
Average Payment	\$16	\$48	\$7	\$18
Average Rent Increase	\$11	\$3	\$3	\$1[b]
Average Rent Increase ÷ Average Payment	0.68	0.07	0.41	0.02

a. Applies with minimum rent plan. The average modal housing cost is \$189 in Phoenix and \$147 in Pittsburgh.

b. The actual simulated estimate is \$0.40.

disequilibrium rent on the potential effect of government rent subsidy programs. As a concomitant to our analysis, we have also reaffirmed the low income elasticities with respect to housing expenditure among low-income renters found by others. Moving transaction costs are high on average among renters in our sample but vary widely between geographic regions and evidently vary a great deal among families as well. By our measure, transaction costs reflect both monetary and non-monetary gains and losses associated with moving that are not captured by measured changes in the value of housing. Moving transaction costs in conjunction with low-income elasticities make government lump-sum transfers very ineffective in increasing housing expenditure among low-income renters. A dollar of unconstrained transfer payment would increase housing expenditure by only 2 to 7 cents in the two cities in our data set. The minimum rent plans have larger effects on average than unconstrained transfers. But families who spend the least on rent are also those least likely to benefit from the minimum rent programs. To obtain payments under these plans, families must surmount the transaction costs associated with moving and must also reallocate income to favor housing in proportions that may be far from their preferred allocations. Thus only a small proportion of families with initial market rents below the minimum will ultimately participate in the programs, even under the more generous plans. Those who do tend to be those with low transaction costs who would move even without the program. And of the total payments to these families, 15 to 32 percent is deadweight loss, according to our estimates.

In addition, we find that because moving transaction costs apparently vary widely among regions, the effects of any given government program are also likely to vary greatly from one region to the other.

As a fortuitous benefit of the data that we used, we were also able to check our model results against experimental results. Our model of moving and housing expenditure seems to predict well the effects of experimental housing programs. Using our model with parameter estimates based on control families, we have simulated the effects of experimental treatments in the housing allowance demand experiment. The model predictions and the experimental results correspond quite closely. The differences that are found can apparently be explained in large part by the impact of self-selection on the estimated experimental treatment effects. The self-determination of enrollment and the attrition inherent in the estimated experimental effects seriously detract from the potential benefits of experimental randomization. Therefore predictions based on our model may be more reliable than those based on the experimental results in this instance. Of course this judgment depends in large part on the experiment having been undertaken so that we could check our predictions against the experimental outcomes.

Appendix A: Some Details of the Probability Expressions

We begin by rewriting the function g in the following form, where the desired proportion of income devoted to housing is $\beta_2 = \delta_0 Y_2^{\delta_1}$, with δ_0 a function of second-period family attributes X_2,

$$g = \ln V_{22} - \ln V_{12} - \ln M$$

$$= (1-\beta_2)\cdot[\ln(Y_2-R_2)-\ln(Y_2-R_1)] + \beta_2[\ln R_2 - \ln R_1] - \ln M$$

(A1)

$$= \ln\left(\frac{Y_2-R_2}{Y_2-R_1}\right) + \beta_2 \ln\left(\frac{R_2}{R_1}\cdot\frac{Y_2-R_1}{Y_2-R_2}\right) - \ln M$$

$$= d + \beta_2 c - \ln M \ .$$

Then the probability that $g > 0$ given R_1, R_2 is

(A2) $$\Pr[g > 0 | R_1, R_2] = \Pr[\ln M - \beta_2 c < d]$$

1. <u>With δ_0 Non-Random</u>

First consider the case with $\eta = 0$ as assumed in equations (11) and (12), in section II-B-1. In this case $\beta_2 = \delta_0 Y_2^{\delta_1} = (X_2\delta)Y_2^{\delta_1}$ and (A2) becomes

(A3) $$\Pr[g > 0] = \Phi\left[\frac{d + \beta_2 c - m}{\sigma_m}\right],$$

where δ_0 (and thus β_2) is independent of R_1 and R_2. To evaluate equations (11) and (12) we simply need, then, the conditional distribution of R_2 given R_1 which is normal with

(A4) $$E(R_2|R_1) = X_2\delta\cdot Y_2^{1+\delta_1} + \frac{\omega_\varepsilon}{\sigma_\varepsilon^2}(R_1 - X_1\delta\cdot Y_1^{1+\delta_1}), \text{ and}$$

$$V(R_2|R_1) = \sigma_\varepsilon^2 - \frac{\omega_\varepsilon^2}{\sigma_\varepsilon^2},$$

where ω_ε is the covariance between ε_1 and ε_2.

2. With δ_0 Random

If δ_0' is random, the probability (A2) that $g > 0$ becomes

(A5) $$Pr[g > 0|R_1,R_2] = \Phi\left[\frac{d - m + E(\delta_0|R_1,R_2)Y_2^{\delta_1}\cdot c}{\sqrt{\sigma_m^2 + V(\delta_0|R_1,R_2)Y_2^{2\delta_1}\cdot c^2}}\right].$$

If we recall that both $f(R_1)$ and $f(R_2|R_1)$ are normal, then the relationships necessary to detail the equations (15) are as follows: (note that these relationships allow a covariance between η_1 and η_2 (ω_η) and allow ε_1 and ε_2 to be correlated (ρ_ε). We then constrain the specification setting $\rho_\varepsilon = 0$ and $\omega_\eta = \sigma_\eta^2$ to yield the primary specification discussed in the text.)

(A6) $$V(R_1) = \sigma_\eta^2 Y_1^{2(1+\delta_1)} + \sigma_\varepsilon^2 ,$$

(A7) $$V(R_2) = \sigma_\eta^2 Y_2^{2(1+\delta_1)} + \sigma_\varepsilon^2 ,$$

(A8) $$\mathrm{Cov}(R_1,R_2) = \omega_\eta (Y_1 Y_2)^{1+\delta_1} + \omega_\varepsilon ,$$

where $\omega_\eta = \rho_\eta \sigma_\eta^2$, $\omega_\varepsilon = \rho_\varepsilon \sigma_\varepsilon^2$.

(A9) $$E(R_2|R_1) = X_2\delta \cdot Y_2^{1+\delta_1} + \frac{\mathrm{Cov}(R_1,R_2)}{V(R_1)} \left(R_1 - X_1\delta \cdot Y_1^{1+\delta_1}\right),$$

(A10) $$V(R_2|R_1) = V(R_2) - \frac{\mathrm{Cov}(R_1,R_2)^2}{\mathrm{Var}(R_1)} ,$$

(A11) $$E(\delta_0|R_1,R_2) = X_2\delta$$

$$+\left[\frac{\omega_\eta Y_1^{1+\delta_1} V(R_2) - \sigma_\eta^2 Y_2^{1+\delta_1} \mathrm{Cov}(R_1,R_2)}{V(R_1)V(R_2) - \mathrm{Cov}(R_1,R_2)^2}\right]\left(R_1 - X_1\delta \cdot Y_1^{1+\delta_1}\right)$$

$$+\left[\frac{\sigma_\eta^2 Y_2^{1+\delta_1} V(R_1) - \omega_\eta Y_.^{1+\delta_1} \mathrm{Cov}(R_1,R_2)}{V(R_1)V(R_2) - \mathrm{Cov}(R_1,R_2)^2}\right]\left(R_2 - X_2\delta \cdot Y_2^{1+\delta_1}\right),$$

$$V(\delta_0|R_1,R_2) = \sigma_\eta^2$$

(A12) $$- \frac{\omega_\eta^2 Y_1^{2(1+\delta_1)} V(R_2) + \sigma_\eta^4 Y_2^{2(1+\delta_1)} V(R_1) - 2\omega_\beta \sigma_\beta^2 (Y_1 Y_2)^{1+\delta_1} \mathrm{Cov}(R_1,R_2)}{V(R_1)V(R_2) - \mathrm{Cov}(R_1,R_2)^2} .$$

3. With the Minimum Rent Subsidy

Most of the elements necessary to detail the equations (19) are the same as those shown in Section 2 above. The only additional elements are the conditional mean and variance of $(\delta_0|R_1)$ and the conditional mean and variance of $(\varepsilon_2|R_1)$. The latter terms derive from $f(R_2|R_1,R^*)$, as mentioned in footnote 1 following equation (18). The relevant particulars are

(A13) $$\mathrm{Cov}(\delta_0,R_1) = \omega_\eta Y_1^{1+\delta_1} ,$$

(A14) $$E(\delta_0|R_1) = X\delta + \frac{\mathrm{Cov}(\delta_0,R_1)}{\mathrm{Var}(R_1)}(R_1 - X\delta\cdot Y_1^{1+\delta_1}) ,$$

(A15) $$V(\delta_0|R_1) = V(\delta_0) - \frac{\mathrm{Cov}(\delta_0,R_1)^2}{V(R_1)} ,$$

(A16) $$E(\varepsilon_2|R_1) = \frac{\omega_\varepsilon}{V(R_1)}(R_1 - X\delta\cdot Y_1^{1+\delta_1}) ,$$

(A17) $$V(\varepsilon_2|R_1) = \sigma_\varepsilon^2 - \frac{\sigma_\varepsilon^2\omega_\varepsilon}{V(R_1)^2} .$$

Appendix B: Simulation Procedure

To simulate the effects of a subsidy plan we suppose that the control families represent a random sample of the families who would be subject to the plan. Thus by averaging the predicted responses of these families, we obtain the average effects of the plan. To give the general idea of our procedure, suppose we begin with the first control observation, characterized by a vector of attributes X. The possible choices of a family with these attributes are determined not only by the vector X, together with the estimated parameters of our model, but by unobserved random components as well.

An important determinant of the effects of subsidy schemes such as housing gap plans is population heterogeneity. Individuals differ in their tastes for housing, moving transaction costs, and the ability to obtain housing at the desired level of rent. In our model, heterogeneous tastes are captured in part by the different measured attributes of families. However, our estimates suggest that not all changes in rent and moving decisions can be completely explained by observed differences in family attributes. The parameter estimates indicate that random variations in tastes (η), maximization errors (ε), and random transaction costs of moving (M) are also important. Our simulation procedure is designed to reflect these random determinants of choice.

Through our model, we have estimated the variance of η, the variance of ε, and the mean of M (with a variance of 1). If we knew the particular values of each of the random terms associated with the observation X, then given our model the rental expenditure, moving, and participation decisions resulting from a subsidy plan would be deterministic. Thus we randomly choose the error terms from the appropriate distributions and then predict the outcome for the observation X. Since we observe R_1 to start, we choose from the estimated distributions conditional on R_1. We must choose values of η, ε_2, and lnM. They are drawn from the following independent normal distributions, with all means and variances based on values estimated in the model:

$$\eta \sim N(E(\eta|R_1), \mathrm{Var}(\eta|R_1))$$

$$\varepsilon_2 \sim N(0, \sigma_\varepsilon^2)$$

$$\ln M \sim N(m, 1)$$

Values of these disturbances together with X and the other estimated parameters of the model completely specify the preference and rental expenditure functions, and thus the moving and rent decisions.

To capture the possible range of responses for a family with observed attributes X, we repeat the process several times for each control family. Thus several simulated outcomes are obtained for each observation X.[1]

The procedure is repeated for each control observation. Average outcomes are obtained by averaging the simulated outcomes, using the total number of simulations given by the number of controls (655) times the number of repetitions for each.

In effect, the repetitions together with averaging are a way of approximating integral expressions like those describing the probability

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1. Our initial simulations were based on 100 repetitions for each control family. Further experimentation with the procedure revealed that 10 repetitions were adequate (and computationally much less expensive), given our rather large sample. Thus most simulations reported are based on 10 repetitions for each of the 655 control families.

of outcomes under the minimum rent plan.

In summary, we emphasize that the important aspect of the simulations is to capture random components of individual choices, in particular heterogeneous preferences among families with the same observed attributes.

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