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GERTCHER, Franklin L.

AN ECONOMIC EVALUATION OF MILITARY FAMILY RESPONSE TO THE CURRENT DEPARTMENT OF DEFENSE HOUSING PROGRAM

University of Hawaii       Ph.D. 1981

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AN ECONOMIC EVALUATION
OF MILITARY FAMILY RESPONSE
TO THE CURRENT DEPARTMENT OF DEFENSE
HOUSING PROGRAM

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE
UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

ECONOMICS

MAY 1981

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ACKNOWLEDGEMENTS

This study could not have been completed without the support, encouragement, and constructive criticism provided by the members of my dissertation committee. I especially want to express my appreciation to Louis A. Rose, my dissertation committee chairman, for his guidance and continuous encouragement over the past two years. Helpful comments and references to the literature were also provided by Walter Miklius, Moheb A. Gahli, Richard Pollock, and Stephen K. Yeh.

My colleagues at the U.S. Air Force Academy also provided support and encouragement. My special thanks goes to Lt Colonel Robert L. Taylor and Lt Colonel William J. Weida for making sure my teaching and work schedule permitted time for this study. Of course, the report itself required the patience and typing skills of two very dedicated ladies, Ms. Ruth Marx and Ms. Joyce DeMeyer.

My special thanks is reserved for my wife Judy for her patience, understanding, and encouragement during this arduous and sometimes frustrating endeavor.
ABSTRACT

This study provides a method for explaining the effects of the current Department of Defense (DoD) housing program on military family housing choice behavior. In addition, this study provides a method for evaluating the current DoD housing program in terms of social benefits and costs and in terms of whether it achieves its stated purpose of increasing the amount of housing service consumed by military families.

Three models are presented. The first model uses the multinomial logit technique to explain housing choice behavior. The model expresses the probability of choice of home ownership, private rental or military rental as a function of the respective differences in the values for the following housing attributes: monthly cost of housing services, distance to work, and number of bedrooms, and the values for the following socioeconomic characteristics: military income, number of persons in family, and the expected period of dwelling unit occupancy. The second model provides a means to estimate net social and net family benefits of military rental housing compared to private market alternatives. The model uses consumer surplus techniques which extend models developed by previous researchers. The third and final model is completely new and provides a method for determining whether the current DoD housing program induces military families to consume more or less housing service than they otherwise would in the private market.

All three models were applied to a representative cross-sectional sample of military families assigned to Travis, Ellsworth, MacDill, and Tinker Air Force bases in calendar year 1978. The results from the
logit model clearly show the effects of the DoD housing program on housing choice behavior. The results are also consistent with the results of previous studies of predominately civilian families. Overall, the results from the benefit-cost model indicate that the DoD housing program obtains a net social as well as a net family benefit for military families. Minor exceptions are noted in the text.

The housing service consumption model indicates that the DoD housing program induces junior and senior enlisted families to consume more housing service than they otherwise would in the private market. On the other hand, company grade families would consume more housing services in the private market. Field grade families consume more housing service at Travis and Ellsworth and they consume less at MacDill and Tinker compared to the private market. However, the results from the benefit-cost model and the housing service consumption model are preliminary and should not be considered conclusive.
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I. INTRODUCTION

Statement of the Problem

Since World War II, Congress and the Department of Defense (DoD) have devoted a good deal of attention to the demand for housing by military families who live on or adjacent to military installations within the continental United States. Also, the quantity and quality of housing available to military families, in some instances, have caused major concern.¹

In light of this general expression of concern and the more pragmatic interest in ways of influencing military family housing consumption behavior consistent with certain government housing policies, it is striking how little is known about the way in which individual military families choose between home ownership, private rental, or military rental housing. For example, the literature does not provide elasticities of the probabilities of housing choice with respect to cost, distance-to-work, income, family size, and certain other independent variables. In addition and to our knowledge, no study has attempted to

¹Public Law 345, August 11, 1955, which amends sections 401 through 409, Title VIII of the National Housing Act, June 27, 1934, is an expression of Congressional concern. Other studies include: Breese, C., Klingembaier, R., et al., The Impact of Large Installations on Nearby Areas: Accelerated Urban Growth, in association with the Bureau of Urban Research, Princeton University, Sage Publications Inc., Beverly Hills, CA., 1965 and The Impact of Military Base Closings, prepared by the University of Kansas for the United States Arms Control and Disarmament Agency, 1960.
evaluate the current DoD program of providing military rental housing on a voluntary basis to military families in terms of social benefits and costs and in terms of whether the program actually increases the amount of housing service consumed compared to private market alternatives.

Thus, the purpose of this study is to first explain the effects of the current DoD housing program on military family housing consumption behavior. Second, we evaluate the current DoD program in terms of social benefits and costs and in terms of whether it achieves its stated purpose of increasing the amount of housing service consumed by military families.

Overview

We set the stage in Chapter II by critically reviewing some of the past studies which have attempted to estimate parameters of the demand for housing generated by essentially civilian populations, using both aggregated and individual household observations. We also review a study which provides estimates of the net benefit of public housing to tenants and a study which provides estimates of the benefits, costs, and waste associated with rent-controlled housing. Finally, we review certain reports which concern the impact of military installations on local communities. Chapter II also identifies certain omissions in the literature which are relevant to the demand for housing by military families, and in particular, relevant to the stated purpose of this study.

In Chapter III, we present a model for estimating a demand function which expresses the probability of choice of home ownership, private rental, or military rental housing as a function of the respective differences in the values for the independent variables in the following
Thus, our model provides a method for estimating demand functions which, in turn, provides a means for statistically explaining the degree of influence that each of the above variables have on housing choice.

It is pertinent at this point to identify some possible applications for estimated demand functions which can be derived from our model. Consider the following. By using observed values for independent variables, our model and the subsequent estimated demand functions provide a means for predicting probabilities of housing choice, which in turn, can be used to assess the impact of large-scale personnel transfers on local private housing markets and on available military housing. Also, the estimated elasticities can be used to predict changes in the probabilities of housing choice caused by government

\(^2\)Regular Military Compensation (RMC) is defined as the sum of basic pay, quarters and subsistence allowances and the tax advantage to the tax exempt status of the allowances. The tax advantage is calculated by determining the amount of additional taxable earnings required to pay the tax and still be left with the same take-home pay.
induced changes in the values associated with one or more of the independent variables. Other possible applications include predicting the impact of changes in military rental housing eligibility criteria and assessing the impact on housing choice due to changes in local housing market conditions; e.g., by changing the values for certain variables in the demand function, our model may offer an alternative to coercing military families to occupy military rental housing if, at a particular installation, they would prefer a private housing alternative. However, we do not use our estimated demand functions for a in-depth analysis of any particular military family housing issue or situation. Such work is relegated to later policy studies, as appropriate.

In Chapter IV, we present a model which permits us to evaluate the current DoD housing program in terms of social benefits and costs.

Before we summarize the nature of our model, consider the following definitions. We define net family benefit as the difference between the benefits and costs which accrue directly to a given family that exclusively consumes a given amount of military rental housing service. We define net social benefit as the social benefits minus social costs associated with the fact that a given family exclusively consumes a given amount of military rental housing service. Net family benefit is therefore a subset of net social benefit; however, as we explain in Chapter IV, we assume that all relevant benefits and costs accrue either to families who consume military rental housing or to the DoD.

We are now ready to summarize the nature of our model. Essentially, our model provides a method for estimating the mean net social benefit
and the mean net family benefit per family in each of four categories: field grade, company grade, senior enlisted, and junior enlisted. We then show that if the mean net social benefit per family in a given category is positive, then the DoD has an economic justification for providing housing service to each family in that category. On the other hand, if the mean net social benefit per family is negative, then society would be better off and each family no worse off, on the average, if the DoD gave each family in that category a cash grant equal to the mean net family benefit. 3

In Chapter V, we present a second model for evaluating the current DoD housing program. This model provides a means for determining whether the program induces military families in various categories to consume more or less housing service than they otherwise would in the private housing market. 4 Our purpose in this instance is to evaluate the effectiveness of the current DoD program in achieving the stated goal of increasing the amount of housing service consumed by military families compared to private market alternatives.

We apply our models presented in Chapters III, IV, and V to individual family observations from Travis, Ellsworth, MacDill, and Tinker

3Certain low income families are eligible for public housing which provides an alternative similar to the military rental alternative available to military families. For example, see Bish, R. L., "Public Housing: The Magnitude and Distribution of Direct Benefits and Effects on Housing Consumption," Journal of Regional Science, Vol. 9, No. 3, 1969.

4As we later explain, we assume that the amount of housing service consumed by a given family in military rental housing represents the DoD standard amount of housing service to which they are nominally entitled.
Air Force bases. Chapter VI provides a summary of the data which are used as inputs to the models presented in Chapters III, IV, and V. Our results are presented in Chapter VII. We briefly discuss policy applications in Chapter VIII, our final chapter.
II. THE LITERATURE ON THE DEMAND FOR HOUSING

Introduction

In this chapter, we review a number of past studies concerned with the demand for housing. The purpose of this review is to establish relationships between what has been done by other researchers and our own contribution.

Beginning with Muth (1960), we review representative studies which concern consumption demand for housing. Our review includes studies which employ time series and studies which employ cross-sectional data. We also review two studies which relate to the benefit-cost analysis that we present in Chapters IV and V; one study concerns public housing and the other evaluates rent controlled housing in New York City. Finally, we review studies which concern the influence of military families on local private housing markets. At appropriate points during our review, we briefly summarize salient aspects of the literature relative to our own work.

Muth's Time Series Work

Almost certainly, the most influential contribution to the demand for housing literature over the past 30 years has been Richard Muth's analysis of the stock demand for housing.\(^1\) Evidence of the importance

of this study is that one can point to many papers about housing markets which have been published since 1960 which cite Muth's work as a reference and--more importantly--reach conclusions partially based on Muth's analysis.

In light of its crucial place in the literature, it is useful to briefly summarize Muth's work and to point out conceptual and practical problems associated with the application of his work to military family housing demand.

Essentially, Muth assumed that the stock demand for housing can be expressed as

$$h_d = b_0 + b_1 p + b_2 y + b_3 r$$  \hspace{1cm} (1)

where $h_d$ = stock demand for housing per capita.

- \( p \) = construction cost of housing.
- \( y \) = income per capita.
- \( r \) = long term bond yield which represents the availability of credit.

He also assumed that the amount of construction which takes place in a year is the sum of two things: the amount needed to replace depreciation (which is assumed to be a constant percentage of the housing stock), and a constant percentage of the difference between stock demand and actual stock. Hence he wrote

$$h_g' = k h + d(h_d - h)$$  \hspace{1cm} (2)

where, in addition to variables already defined,

- \( h_g' \) = per capita housing construction.
- \( k \) = the depreciation rate.
- \( h \) = actual housing stock per capita.
d = percentage of excess demand which market supplies in a year.

Substitution of Equation (1) into Equation (2) allowed Muth to eliminate the unobservable \( h_d \) term and hence to obtain the following equation which can be estimated using regression techniques.

\[
\hat{h}_g' = db_0 + db_1p + db_2y + db_3r - (d-k)h
\]

(3)

The estimated coefficients from this regression along with an a priori assumption about the value of the depreciation rate then allowed Muth to estimate the parameters of his stock demand equation.

There are problems with this technique, both theoretical and practical. On a theoretical level, there appears to be a number of factors missing in Muth's analysis. For instance, there are no demographic variables except for putting everything into per capita terms. Also, Muth omitted any explicit consideration of the effects of taxes and operating costs.

Relative to military families, Muth's model does not disaggregate the housing market into component sectors, i.e., individual military families, in most cases, may choose to obtain a housing unit in either the (1) home ownership, (2) private rental, or (3) military rental sector. If these sectors behave in significantly different ways, the absence of disaggregation may lead to errors, and at the very least failure to disaggregate would appear to be costly in terms of lost information which would be potentially useful in policy analysis.

On a more practical level, we note that Muth's empirical results are based on data which begin in 1915 and end in 1941 (World War I years excluded). Hence Muth's estimates are based upon observations all of which are over 39 years old and more than a third of which are years of
the Great Depression—hardly typical economic circumstances.

**Lee's Time Series Study**

Tong Hun Lee, in two papers in the *Review of Economics and Statistics*, criticized the work by Muth and obtained time series results of his own. Lee's principal criticism lies in Muth's overly simplistic use of credit variables. In his own computations, Lee attempted to include a complex of various influences on credit. Specifically, Lee used a composite credit variable which is essentially the product of the mortgage payment and the repayment period of the mortgage loan in order to take into account the effect of the repayment period. This approach has been criticized, however, in that it involved the implicit assumption that borrowers are indifferent about when payments are made. Hence there is some question about the adequacy of Lee's credit term, though it probably represents some improvement over Muth's single credit variable.

Lee also modified slightly Muth's attempt to correct for demographic changes. He deflated his variables using number of families in the population rather than using the population figure itself which Muth used.

With these exceptions, however, Lee's analysis is very similar to

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3 This conclusion was initially reached by Ohls. See Ohls, James C. A Cross-Section Study of Demand Functions for Housing and Policy Implications of Results, Dissertation, University of Pennsylvania, 1971.
that of Muth both in terms of its conceptual specification and of the data used. Hence most of the criticisms made above concerning the Muth paper would appear to apply to Lee's analysis as well.

**Recent Time Series Work**

More recent time series work concerning demand for housing (for example, Taubman and Rasche, 1971) follows a somewhat different approach. Taubman and Rasche argued that given the construction lags which are present in the housing market, the factor which serves to clear the market in the short run is not quantity adjustments but price adjustments. Hence they argued that the proper specification of the regression equation in time series is to make the price of housing the dependent variable in the equation. Therefore they converted the stock demand equation into an equilibrium rent equation and they postulated that the change in market rents during a year is a lagged function of the difference between actual and equilibrium rent, and it is this model that they estimated.

While this and other analyses represent improvements over Muth's work both in utilizing more recent data and in attempting more realistic specifications of the model employed, they each share some of the same general weaknesses of time series work. For instance, Taubman and Rasche made no attempt to examine the effects of demographic variables except for simply taking account of changes in the number of households. In addition, no time series study provides any information about the switching behavior of families as they go from one sector of the housing market to the other. Also, the Taubman-Rasche analysis is carried out for only one portion of the rental sector of the housing market--
multi-family apartment buildings.\textsuperscript{4}

We now conclude our review of studies which estimate demand functions based on aggregated time series data. One apparent reason why this past work has failed to yield conclusive results concerning the parameters of the function relating housing demand to price and income is that time series data on housing markets are highly influenced by short term supply conditions, particularly conditions in credit markets (mortgage interest rates, credit terms, etc.). Because housing markets are particularly sensitive to volatile credit market conditions, it appears to be very difficult if not impossible to use time series data to draw meaningful conclusions about underlying demand relationships. This is true simply because it is very difficult to separate the effects of long run changes in demand from the effects of the poorly-understood short run credit fluctuations.\textsuperscript{5} Time series analysis is also complicated by such factors as strikes and even weather variations which affect the supply of new housing units. In our study, we therefore alleviate the problems associated with the use of time series data by using cross-sectional data associated with individual families.

We now turn to a review of certain studies which estimate demand functions based on cross-sectional data, both at the aggregate and the individual family (micro) level.

\textsuperscript{4}The work of Taubman and Rasche was not available for review, thus the above analysis is based on a review by Ohls (1971), op. cit. Ohls cites a paper by Taubman and Rasche as follows: Taubman, P. and Rasche R.: Tax Law and the Apartment Building Industry, unpublished manuscript, 1971.

\textsuperscript{5}See Ohls, op. cit.
Reid's Cross-Section Study

Drawing principally on data from the 1950 Census, Margaret Reid completed an extensive cross-section analysis of the relationship between housing demand and income. Reid used census tract data for individual cities and regressed mean housing purchased on mean census tract income. Essentially this can be interpreted as an attempt to estimate a market demand equation from submarkets made up of census tracts.\(^6\)

This procedure has been criticized in the literature, however, on the grounds that grouping families by census tract may impose a bias caused by the fact that housing is affected by externalities from one house in a neighborhood to another. Hence it is probably the case that families with a relatively strong taste for housing are attracted to relatively high income areas where housing is relatively good while families with relatively weak tastes for housing may tend to cluster disproportionately in relatively low income areas with poorer housing. Grouping observations by census tract as Reid has done is likely to lead to the presence of large numbers of people with abnormally high preferences for housing in the high income groups and to the presence of relatively large numbers of people with abnormally low preferences for housing in the low income groups. And this, in turn, may cause an upward bias in estimated income coefficients. As a final note, census tract observation points do not permit observed variations in price.

Consistent with the purpose of our study, we alleviate the possible bias in estimated income elasticity by using individual household (military family) observations. Also, our data permits the inclusion of an opportunity cost variable, which, for the purpose of our study, helps explain the observed variation in price-quantity combinations across individual households.

**Muth's Cross-Section Study**

In work quite similar to that of Reid reported above, Muth attempted to use between-city data to compute a housing stock demand equation by regressing the city mean market value of owner occupied houses on income and the Boechk cost index.\(^7\) This work also has problems with the price variable; specifically, the price variable is essentially construction cost and does not adequately reflect the market price faced by individual families.

**Lee's Cross-Section Study**

In addition to his efforts to modify Muth's time series work, T. H. Lee also attempted to estimate income elasticities using data from the Michigan Surveys of Consumer Finances.\(^8\) This work is unlike the work reviewed so far in this chapter in that it is based not on groupings of families but rather on individual family observations. A weakness which Lee's work shares with the other studies described above,

\[^7\text{Muth, op. cit.}\]

however, is that he gives inadequate attention to prices. Lacking any information on prices, Lee did not include a price variable in his regressions. This is both grounds for some doubt concerning the reliability of his results and also makes his analysis impossible to use in evaluating the effects of DoD military family housing policies which involve consideration of a price variable.

**deLeeuw's Cross-Section Work**

Frank deLeeuw attempted to use SMSA cross-section data to estimate both rental and owner-occupied housing demand relationships. In both cases, deLeeuw estimated the price and income elasticities of demand to be in the vicinity of 1. As his price of rental housing variable, he used the rental component of a 1959 Bureau of Labor Statistics typical city worker budget cost study. For a sample of 19 metropolitan areas, he then regressed median gross rental expenditures, deflated by the price index, on price and median income to estimate a demand function for rental housing service. Using median purchase price instead of median rent, he used a similar procedure to estimate a demand function for owner-occupied housing service.

deLeeuw's work appears to be a significant advance in the literature in that it represents a serious attempt to use a housing service price variable rather than a construction cost price variable in the estimation of a housing service demand relationship.

However, deLeeuw's data allowed only median income and median

---

rent as a basis for income and rent components in his demand function for rental housing and median income and median purchase price as a basis for income and rent in his demand function for owner-occupied housing. For the purpose of our study, we prefer to use individual household observations to avoid possible bias in elasticity estimates caused by skewness in military income in housing purchase distributions.

**Ohls' Cross-Section Study**

We now turn to a study by James C. Ohls which provides a two-sector model of housing demand. Ohls set up a two-sector demand model for both rental and owner-occupied sectors of the private housing market. He then used standard linear regression analysis to estimate demand functions,\(^{10}\) He also used probit analysis to investigate switching between home ownership and private rental sectors. Given the relative importance of Ohls' work to our model in Chapter III, we summarize Ohls' model and empirical equations in the following paragraphs.

Ohls stated that the basic individual buying unit in the private housing market is the family or household. He began his examination of the demand for housing services by considering the family's decision process with regard to housing markets. The first decision which the family must make with regard to housing is that of deciding which of the two sectors of the housing market to enter. Typically, a family buys its housing in one or the other of the sectors but not in both. Casual observation and economic theory suggest that in making this initial decision the family is influenced by its income, by certain demographic

\(^{10}\) Ohls, op. cit.
characteristics of the family—perhaps number of children, age of family, race, etc.—and possibly by the relative price of housing in the two sectors of the market. Hence Ohls modeled this decision by writing

\[ \text{Sect}_k = S(Y_k, \frac{P_1}{P_2}, D_{1k}, D_{2k}, D_{3k}, \ldots) \]  

(1)

where \( \text{Sect}_k \) is a two-valued variable indicating which sector of the housing market the \( k \)th family chooses to enter.

- \( S \) = The decision function.
- \( Y_k \) = The family's income.
- \( P_s \) = The relative price of housing in the \( sth \) sector.
- \( D_{jk} \) = The \( j \)th demographic characteristic of the \( k \)th family.

Once the family has chosen one sector of the market or the other, its next decision is to decide how much housing service to buy. Ohls indicated that this decision will depend on the family's income, on the price of housing in the market in which the family is buying housing, and on certain demographic variables. Ohls modeled this decision on

\[ \text{QD}_{sk} = f(Y_k, P_s, D_{1k}, D_{2k}, \ldots, \text{Sect}_k) \]  

(2)

where, in addition to the variables already defined,

- \( \text{QD}_{sk} \) = The amount of housing services which family \( k \) demands in sector \( s \) of the housing market. (Note that if the family is buying its housing in the sector of the housing market other than the \( s \) sector, \( \text{QD}_{sk} = 0 \).)

Also, Ohls followed Muth et al., in his definition of housing service units, and he implied that these units are indistinguishable between sectors.

Ohls then used probit to analyze the choice of families between private rental and home ownership. Using \( I \) as an index of the
likelihood of a family choosing to rent, Ohls gave us

\[ I = f(Y, \frac{P_1}{P_2}, D_1, D_2, D_3 \ldots) \] (3)

where the arguments in parentheses are consistent with those in equation (1).

For his empirical work, Ohls used individual family observations from a survey conducted in 1966-1967 by the U.S. Office of Economic Opportunity. Observations on families in 11 major cities were used. He estimated demand functions for the rental and owner occupied sectors as follows:

A rental demand equation:

\[ QD_1 = 61.0 - 21.6P_1 + 0.0045Y + 1.3Ch1d + 5.3Wte + 3.7West \] (4)

And an owner-occupied demand equation:

\[ QD_2 = 9053 - 7483P_2 + 0.95Y + 6700Dummy + 4700Wte \] (5)

Where

- \( Y \) = Annual real family income.
- \( P_1 \) = Relative price of rental housing.
- \( P_2 \) = Relative price of owner occupied housing.
- \( Wte \) = Dummy variable which is 1 if family is white.
- \( West \) = Dummy variable which is 1 if family lives in west.
- \( QD_1 \) = Deflated monthly family rent bill.
- \( Ch1d \) = Number of children in family.
- \( QD_2 \) = Deflated value of owner occupied house.
- \( Dummy \) = Dummy variable which varies by cities.
Ohls' switching equation was:

\[ I = 2.1 - 0.000089Y - 1.15 \frac{P_1}{P_2} - 0.64Wte - 0.21West \]  \hspace{1cm} (6)

Where in addition to the variables listed above, I is the probit index.

Ohls went on to use his estimated sectoral demand equations and his switching equation to examine the implications of certain possible federal government policies which concern private housing markets. However, we will not elaborate on his policy analysis, since it bears little relationship to our own work.

Compared to the purpose of our own work, we note that Ohls was only concerned with housing demand in the private market; a public (or military) housing option was not considered. Also, his estimated equations were based on overwhelmingly civilian family populations rather than exclusively military families.

Also, Ohls expressed disappointment with the empirical results of his switching equation. Specifically, he tried a demographic variable which indicated the presence of children. The coefficient for this variable had a positive sign, which indicated that families were more likely to rent if they had children, which, according to Ohls, was contrary to common observation.

We agree with Ohls' statement that home owners generally consume more housing service than private renters, however, we find it curious that Ohls expected a negative coefficient for family size in his switching equation, since for a given income class, it seems reasonable to expect that the probability of renting would initially decrease but eventually increase as family size increased because the budget constraint may force larger families to substitute non-housing goods for
housing consumption. (We elaborate on this statement in Chapter III.)

However, despite the limitations of Ohls' model and empirical work relative to our own study, we acknowledge that Ohls provided conceptual background for our own three-sector demand model which concerns the probabilities of housing choice as a function of the variables presented in Chapter I.

A Logit Model of Home Ownership

We now turn to a logit model of home ownership developed by Mingchi Li, who adapted the logit method to an analysis of home ownership. Essentially, Li assessed the significance of all possible multidimensional interaction effects between four basic family characteristics: age of head, race, income, and family size.

To determine all possible interactions, he constructed a total of 44 different logit models, each of which expressed the probability of home ownership as a function of an additive and/or a multiplicative combination of the above four characteristics. By evaluating the estimated coefficients associated with each logit model, Li assessed the relative importance of the interactions and interpreted the results of his analysis in light of existing theories of housing consumption behavior.

Li's models differ from our own in several important respects. First, Li considered only private rental and home ownership; a third option, i.e., public (or military) rental housing, was not considered. Also, Li included only four family characteristics; housing attributes (including a price variable) were not considered. In contrast, our

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model includes both family characteristics and housing attributes as independent variables. We therefore expect that our model will have more explanatory power, in a statistical sense, compared to Li's with regard to military families.

However, we acknowledge that Li's analysis of the interaction between income and family size provided valuable background for our own study. Specifically, Li tested whether the probability of home ownership increased or decreased as a function of family size, holding income constant. We employ essentially the same test.

**Other Cross-Section Studies**

Several other cross-sectional studies were reviewed (Barth, 1966; Goulet, 1970; Goldstein, 1970; and Quigley, 1976). However, with the exception of Quigley, the studies surveyed were concerned with aggregate demand functions, not individual family choice. Quigley considered individual family choice of dwelling unit type strictly within the rental housing sector; we therefore find that his study bears little relationship to our own work.

To this point, we have reviewed the literature which essentially concerns housing demand functions for the general population. We have

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12 The literature surveyed included all dissertations on housing which were listed in the Comprehensive Dissertation Index, 1898-1977. In addition, numerous journal articles on housing were researched, and the references listed in the bibliographies of these articles were also researched.

pointed out certain similarities and limitations in the literature with regard to our own study, especially at the individual family, or micro level. Indeed, a key objective of this study is to report on the results of an attempt to use some previously untapped cross-section data on military families to estimate certain parameters of the demand for housing at the individual family level. These parameters will be compared, insofar as possible, with certain estimates made in the studies thus far reviewed.

As stated in Chapter I, we are also concerned with the net social and net family benefits of military rental compared to private market alternatives. The following reviews concern a paper by Bish on the direct benefits of public housing and a paper by Olsen on rent controlled housing in New York City. The techniques of analysis used by these authors offer a starting point for our models in Chapters IV and V.

A Study of the Direct Benefits of Public Housing

Bish's model provides a method for estimating the direct benefits which accrue to families who occupy government provided, low cost public housing. Bish defined the direct benefit to a family as the private market value of the increase in housing service consumption without an increase in individual family outlay. Assuming a unitary elastic demand curve for housing service, Bish's model provides a consumer surplus measurement which approximates the value of the direct benefit as defined above. Using a cross-section sample of 836 families

in eight geographically separate projects, Bish used his model to estimate that U.S. public housing provided 197,245,932 dollars in direct benefits to all occupants in 1965.

Bish's model has limited applicability with regard to our own work. First, as Bish pointed out, his measure is not alone sufficient for an efficiency analysis of the public housing program because it gives no consideration to costs and benefits which may accrue to other members of the community in which the public housing is located. Second, Bish assumed that a family which occupies a public housing unit must be on its housing service (quantity variable) demand curve. Actually, there is no a priori reason to assume that a family in public (or military) housing must be on its housing service demand curve. In practice, the actual amount of housing service selected by a given family in public housing could be constrained by the housing unit offered as well as the family budget. As we explain in Chapter IV, a family in public housing may be on, to the right, or below its housing service (quantity variable) demand curve. Finally, Bish assumed that the next best alternative compared to public housing is private rental housing. While this assumption is appropriate for an analysis which includes only low income civilian families, it is not appropriate for an analysis which includes low, moderate, and relatively high income military families.

In sum, we acknowledge that Bish's consumer surplus approach

\[15\] Bish used an index of quality and quantity for a single dwelling unit. In Chapter IV, we point out that this index is essentially the same as a housing service unit, which was used initially by Muth, Olsen, and later by many other researchers.
provided conceptual guidance with regard to our own study. However, his model cannot be applied, in whole or in part, to our analysis of the benefits and costs of military rental housing service compared to private market alternatives. Essentially, Bish's model provides no method for estimating net social benefit, and his measure of direct benefit is based on assumptions which are unrealistic with regard to the observed behavior of military families.

An Econometric Analysis of Rent Control

We now turn to a study by Edgar O. Olsen, which provides a comparison of private rental housing to rent controlled housing. The purposes of Olsen's paper are to provide a general method for answering questions about rent control and to specifically answer questions about rent control in New York City in 1968.\textsuperscript{16}

Olsen's analysis and empirical work concerning rent control are tangential to our own analysis of the net family and net social benefits of military rental housing. However, his consumer surplus model is indeed relevant and provides essential background for our work. We therefore provide a brief review of his model and indicate its relationship to the model we present in Chapter IV.

Olsen began with the following assumptions and definitions. First, we have two goods: housing service and all other goods. Second, we have three markets: the controlled rental housing market, the uncontrolled housing market, and the market for all other goods. Also, 

Olsen assumed that we have perfectly elastic supply curves in the uncontrolled housing market and in the market for all other goods, and the long run supply price in the uncontrolled market is uneffected by the existence of rent control. Finally, Olsen followed Muth by defining a housing service unit as an index of both quantity and quality attributes of housing (we elaborate on this definition in Chapter IV).

Next, Olsen constructed a consumer surplus model which permitted estimates of benefits in terms of specified portions of the area under the housing service (quantity variable) demand curve. Specifically, his model provides a means for estimating the net benefit of rent control to the tenant of a rent controlled dwelling and the net loss to the landlord. By adding an exogeneous estimate of administrative costs, Olsen was also able to provide a means to estimate the waste which accrues to society as a whole.

In Chapter IV of this study, we present a consumer surplus model which is quite similar to Olsen's. However, Olsen was able to show empirically that the amount of housing service consumed by a tenant under rent control was generally less than the amount that would have been consumed in the uncontrolled market. This empirical evidence permitted him to simplify his consumer surplus model considerably. We have no empirical evidence to show that the amount of housing service consumed by a family in a military rental unit is generally less than the amount that would have been consumed in the private sector. We are therefore unable to make a similar simplification to our model, and in a sense, our model therefore represents an extension to Olsen's work. Details are provided in Chapter IV.
We now review the literature which specifically addresses the influence of military families on the demand for private housing. The Breese, et al. report provides analyses of the impact of large industrial and military installations on nearby urban areas. The report consists of five case studies, a summary, and recommendations.

The primary objective of the report was to identify both the characteristics of impact patterns and the devices for anticipating related events and issues. A secondary objective was to suggest procedures or methods for dealing effectively with the impact situation during its various stages of development. The report made no attempt to deal with the impact of the withdrawal of large installations from communities.

The third case in the report was, in part, relevant to our research. This case concerned an investigation of the reactivation of Dover Air Force Base in mid-1952 in the vicinity of Dover, Delaware. The study focused on the decade 1952-62, and provided a descriptive analysis of the impact of the reactivation on population trends, ecology, the local private economy, housing, and local governments. The Dover case provided an excellent descriptive analysis of the spatial pattern of housing surrounding Dover Air Force Base. A 1962 Dover family housing survey showed that 4,201 military personnel resided in private housing and 1,255 resided in military family housing. An additional 3,342

single officers and enlisted personnel lived in military barracks. However, Breese, et al. made no attempt to develop a model of housing choice or to assess the costs and benefits associated with the provision of military family housing. We therefore merely note the descriptive nature and value of the study.

Studies on the Economic Impact of Military Base Closings

When a military base within the continental United States is closed, an impact study is, by Federal law, always prepared. We reviewed a collection of case studies in a report by the University of Kansas staff. This report specifically addressed the economic impact on local urban areas resulting from the closing of nine military bases within the continental United States during the mid-1960s. The method employed was time-series trend analysis for local economic and demographic variables.

With respect to housing, the case studies in the report dealt exclusively with the impact on the stock of private housing caused by the departure of military personnel who, while assigned to the base, lived in private housing. Construction, vacancy rates, and home mortgage foreclosure trends were evaluated. Again, while the report has descriptive value, we note the lack of application of economic theory to the issues of housing choice and the costs and benefits of military

rental housing. 19

Summary and Conclusions

In this chapter, we have reviewed a number of studies concerned with the demand for housing. The purpose of our review was to establish relationships between previous studies and our own contribution. Throughout this chapter, we have identified instances where the theoretical approach taken by other researchers provided conceptual guidance for our work. We also noted instances where the approach taken by others could not be applied to an analysis of military family housing choice or to an evaluation of the current DoD housing program. We are now ready to summarize our findings with regard to the work of other researchers compared to our own.

First, we note that studies based on aggregate demand do not capture the influence that cost, income, and various socioeconomic variables have upon the housing selections made by individual

families. Thus, we reject the aggregate demand approach as a conceptual framework for our analysis of military family housing choice behavior.

Second, even at the theoretical level, no previous study considered a choice between dwelling units across three housing sectors. It is possible that owner-occupied, private rental, and military rental dwelling units are substitutes, and the demands in the three sectors are likely to be interdependent. The probit and logit models of housing choice developed by Ohls and Li, respectively, provide conceptual guidance for our model presented in Chapter III. However, their respective models were concerned with choice between home ownership and private rental, a third option, i.e., military rental, was not considered.

20 See Theil, H. Principles of Econometrics, John Wiley and Sons, New York, 1971, pages 368-370 and 657-660. Essentially, Theil points out that when we use only sample means for the aggregated values of a given variable for a regression, we introduce the use of a statistical distribution which implies a degree of uncertainty due to the unknown measure of dispersion about each sample mean. Thus, with only a series of sample means (or other measure of central tendency), we lose a potentially significant amount of information concerning the specific characteristics of the independent variable and hence, the degree of influence of that variable upon the dependent variable in the regression. Theil goes on to point out that even if we add other variables to the regression, we do not reduce the degree of uncertainty for any variable which is measured only by a series of sample means. We conclude then, that actual observed values of our independent variables are preferable to sample measures of central tendency based on aggregated data.

21 For example, military families in the United States commonly face this choice each time they are assigned to a different installation. Based on a fiscal year 1978 survey of 29,000 military families, 11,500 chose home ownership, 4,200 chose private rental, and 13,300 chose military rental (Department of Defense) housing.
Further, Li's models did not include housing attributes as independent variables, and Ohls' probit parameters are not directly comparable to our logit parameters, except in terms of sign. Thus, we provide a theoretical model in Chapter III which allows for individual military family choice between dwelling units across all three sectors of the housing market. For reasons which are presented in Chapter III, the model includes both relevant housing attributes and family socioeconomic characteristics as variables in the individual family demand function. In so far as possible, we will make comparisons between the parameters estimated by Ohls and Li and our own results in Chapter VII.

Third, no study available to us attempted to evaluate the current DoD housing program in terms of net social benefits and in terms of whether the program induces military families to consume more or less housing service compared to private market alternatives. Bish estimated the net direct benefits of public housing for essentially civilian families, however, for reasons stated earlier, we cannot apply his model to an evaluation of the current DoD housing program. Olsen's consumer surplus model provided essential conceptual guidance, however, he based his analysis on certain simplifying assumptions which cannot be incorporated in our own analysis. We therefore extend the concepts provided by Bish and Olsen in our models which are presented in Chapters IV and V.

Finally, we acknowledge the descriptive value of certain DoD sponsored impact studies. For example, the Breese, et al. report provided an excellent ex post summary of facts which concerned the choices of military families with regard to home ownership, private rental, and military rental housing under various economic conditions.
Also, the Breese report provided an excellent descriptive analysis of the spatial pattern of housing surrounding certain military installations.

We close this chapter by noting that other studies, some of which were mentioned earlier, also provided indirect guidance for our work. However, the studies by Ohls, Li, Bish, Olsen, and Breese were of special importance; we have therefore included the salient aspects of their work in this summary.
III. A MODEL OF HOUSING CHOICE BEHAVIOR

Introduction

In this chapter, we present a model which provides a method for explaining the effects of the current DoD housing program on military family housing choice behavior. Specifically, we present a theoretical model for estimating demand functions which express the probability of choice of home ownership, private rental, or military rental as a function of the independent variables which were listed in Chapter I, Table 1. In the following table, we repeat these variables and add symbols which will be used in the subsequent analysis.

TABLE 2
INDEPENDENT VARIABLES IN THE DEMAND FUNCTION

\[ x_1 \] Monthly cost of housing service (absolute amount)
\[ x_2 \] Distance to work
\[ x_3 \] Number of bedrooms
\[ y_1 \] Income (RMC)
\[ y_2 \] Number of persons in family
\[ y_3 \] Expected period of dwelling unit occupancy

In the above table, the variables identified by the \( x \) symbols are housing attributes and the variables identified by \( y \) symbols are family
socioeconomic characteristics. Later in Chapter VII, we use our model to estimate demand functions which permit us to statistically explain the degree of influence that each attribute \( x \) and characteristic \( y \) has on housing choice behavior.

Overview

We have organized the remainder of this chapter in the following manner. In the third section which immediately follows, we set up the problem of housing choice, state our assumptions, and discuss our explanatory variables. In the fourth section, we show that the multinomial logit model is an appropriate vehicle for theoretically and statistically explaining military family choice of housing sector. We then present our theoretical model. In the fifth and final section, we briefly discuss our empirical model and the expected signs associated with each of our explanatory variables.

Theory

We are now ready to set up the housing choice problem faced by a military family that seeks to obtain a dwelling unit in one of three possible housing sectors. Essentially, we assume that a family will choose the dwelling unit that maximizes its utility as conditioned by the family socioeconomic characteristics listed in Table 2. We also assume that the dwelling unit attributes listed in Table 2 are part of each family's utility function. It follows then, that the choice of a dwelling unit from a particular sector may be explained in terms of the differences in dwelling unit attributes across sectors and the differences in socioeconomic characteristics across families.
We also assume that all families considered in this study have freedom of choice between three alternative housing sectors. Our model does not apply to families who are not eligible for military family housing, and it does not apply to installations which coerce military families to occupy military rental units.¹

Finally, we assume that the differences in waiting periods for dwelling unit occupancy represent a negligible factor in the choice between housing sectors. We base this assumption on the following

¹DoD Instruction 4165.44 dated 28 January 1975 provides overall guidance for determining eligibility criteria for military rental housing for all military service departments. Air Force Regulation 90-1 implements DoD 4165.44 in the Air Force. Similar regulations have been published by the Army and Navy. DoD Instruction 4165.44 insures that eligibility criteria are consistent for all three military service departments.

Air Force Regulation 90-1 outlines the criteria for eligibility for military rental housing in the Air Force. Essentially, Air Force members in pay grades E-4 or above, with at least two years active duty or an obligation of six years, and who are eligible for Basic Allowance for Quarters (BAQ) at the dependent rate, are eligible for military rental housing. This includes female members who have dependents in their own right. Air Force members are assigned housing units according to rank and family composition.

Since we estimate demand functions using data from Travis, Ellsworth, MacDill, and Tinker Air Force bases later in this study, we discussed military rental housing eligibility policy with responsible officials in base housing offices at these four installations. Based on DoD Instruction 4165.44, subsequent regulations, and our discussions, we believe that in fact, the vast majority of Air Force members with families in pay grades E-4 and above have relative freedom of choice between home ownership, private rental, and military rental housing sectors within the continental United States.

Further, we have confirmed that in calendar year 1978, the United States Air Force Academy was the only major Air Force installation in the continental United States that had a policy of coercing Air Force members to occupy military rental housing. Members with families were faced with a loss of BAQ if they chose private housing. However, even in this extreme case, Air Force members who appealed this potential loss of BAQ succeeded in having it re-instated within one month. Reference: conversations with Lt Col David E. Roberts and Mr. Christie, Headquarters U.S. Air Force, Directorate of Engineering and Services, Housing and Services Division, and officials at the Base Housing Office, U.S. Air Force Academy, August-September 1979.
empirical evidence.

In the vast majority of cases, military families make the housing sector choice decision only when they move from one installation to another. When a family arrives at a new installation, temporary housing is normally available. Further, the DoD provides extra temporary allowances and payments which cover temporary living expenses. Thus, most families have adequate time to search for housing and adequate funds to wait until a dwelling unit in the desired sector becomes available.

We also note however, that waiting lists for the military rental option are common at most military installations. At the four installations considered later in this study, the waiting period to obtain a military rental dwelling unit ranged from 0 to 90 days from the time of arrival on station in 1978, with a mean period of about 56 days. The mean periods for private rental and owner occupancy were eight days and 28 days, respectively. However, for the reasons cited above, we believe that in the vast majority of cases, these differences do not significantly affect housing choice between sectors. This opinion is also held by responsible officials at the installations included in this study.

We are now ready to discuss the variables which explain the probabilities of choice with respect to housing sector. Conceivably, all dwelling unit attributes which have differences across sectors and all characteristics which have differences across families could influence the probability of choice associated with a given sector. We therefore include both attributes and characteristics as explanatory variables. Table 2 identifies those variables which our later analysis
shows have significant explanatory power. Of course, we permit those variables not included in Table 2 to enter our model through the error term.

In the context of our model, $x_1$ is the uniform monthly cost, or imputed rent, to a family of the housing services yielded by a dwelling unit. The measurement of $x_1$ poses different problems in each of our three sectors. In the following paragraphs, we discuss the measurement of $x_1$ in each sector.

We begin with military rental. Families who reside in military rental housing forfeit their basic allowance for quarters (BAQ) in exchange for military rental housing services. All other costs, including utilities and repairs, are paid for by the DoD. Thus, for the purpose of this chapter, the forfeited BAQ represents the complete monthly rental payment experienced by each family that consumes military rental housing services. This forfeited BAQ is directly observable from the data.

Now consider the imputed rent for a private rental dwelling unit. The following table identifies the cash flow experienced by a military family that consumes private rental housing service.

<table>
<thead>
<tr>
<th>TABLE 3</th>
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<tbody>
<tr>
<td>COSTS ASSOCIATED WITH PRIVATE RENTAL</td>
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<tr>
<td>Monthly rent payment$^2$</td>
</tr>
<tr>
<td>Average monthly utility payment</td>
</tr>
<tr>
<td>Damage deposit</td>
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<tr>
<td>Renter's insurance</td>
</tr>
</tbody>
</table>

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$^2$ We assume that monthly rental payments are relatively stable for a
These and other miscellaneous payments were totaled and averaged on a monthly basis by each private renter family included in our sample of military families. Thus, our imputed rents for private rental dwelling units can be taken directly from our data.

Now consider the imputed rent for an owner-occupied dwelling unit. Table 4 identifies the cash flow experienced by a family that selects home ownership. We use this cash flow to calculate an imputed uniform monthly rent. With the exception of selling price and federal income tax, the amounts in the following table are self-explanatory.

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Given family over a normal tour length at a given military installation. We base this assumption on the fact that most military families in private rental housing obtain one to two year renewable leases, and that in most cases, increases in rent at lease renewal tend to be either zero or very small. See the DoD annual housing survey summaries for the years 1975-78 for MacDill, Ellsworth, Travis, and Tinker Air Force bases for further details.

The data available for this study do not permit explicit consideration of capital gains tax due to the sale of a home. Implicitly, we assume that any expected capital gains tax is included as an adjustment to the selling price. It is of interest to note that a capital gains tax need not be paid if a home owner sells a home and buys another within 18 months of the sale, provided the purchase price of the new home equals or exceeds the selling price of the old home. For military families, the 18 month time limit may be extended upon request up to four years, depending on active duty commitments. Refer to the Uniformed Services Almanac (1978), L. Sharff and S. Gordon, ed. Also, note that Table 4 includes "expected period of occupancy." Thus, $y_3$ is incorporated into the calculation of $x_1$. However, we cannot assume that it is entirely incorporated. This statement is supported by the results shown in the correlation matrix of our initial computer runs with the probit model. (See Chapter VII.) We therefore include $y_3$ as a separate variable in Tables 1 and 2.
We now consider the family's estimate of the future selling price of their home at the end of their expected period of occupancy in more detail. First, estimates of expected selling price may reasonably vary. It is therefore worthwhile to expressly recognize the propensity to be biased in estimating the future selling price of a home. Table 5 portrays forecasts which were made based on past regional median selling prices of existing single family homes for four regions within the continental United States. 4

4The time series data for selling price forecasts were taken from
The definitions for the above forecast sets are as follows:

Group 1 (AG1): Within the range of realism, make those forecasts which are optimistic with respect to owning a home.

Group 2 (AG2): Make those forecasts which reflect the most realistic expectations with respect to owning a home.

The following simple predictive model was used to make AG2 forecasts of the expected median selling price:

\[ X_t = Ae^{\beta t} \]

where \( X_t \) is the median regional selling price of existing single family homes in year \( t \). Data included observations for years 1968 through 1978. An average annual appreciation rate over the next decade was calculated for each region based on the slope of the function \( X_t = Ae^{\beta t} \) evaluated for the years 1979-88. Obviously, the above predictive model "explains" nothing, since appreciation rates are actually a function of certain fundamental housing market variables. Basically, we assumed that the fundamental variables will continue to interact over the next decade in the same way as they did during the past decade, and that time is a satisfactory proxy for predictive purposes over the relatively short term of ten years. In any case, it is certainly plausible that prospective home buyers will continue to expect that homes will appreciate in the future as they have in the past, and that expected selling price is a relevant variable in housing choice behavior. AG1 and AG3 estimates of appreciation rates are based on an analysis of variance from AG2 values of \( X_t \). As a final note, we tried other models for predictive purposes, including an Almon lag model, a moving average model, and a simple linear least squares model. Unfortunately, technical problems with the Almon lag model severely limited its usefulness. The moving average model has theoretical limitations which made it unsuitable for this application. Specifically, a moving average model provides relatively accurate forecasts if the dependent variable (median regional selling price) is stable with respect to the independent variable.
Group 3 (AG3): Within the range of realism, make those forecasts which are pessimistic with respect to owning a home.

Now consider the federal income tax benefit for home owners. If home owners were taxed like other investors, they would have to report as income the gross imputed rent on their homes. Like other investors, home owners would be allowed to deduct maintenance, depreciation, interest, and property taxes as expenses incurred in earning this income. Net rent, which is the difference between gross imputed rent and the above expenses, would be included in taxable income. However, home owners do not have to include gross imputed rent on their tax returns, although they are permitted to deduct mortgage interest and property taxes. Thus, taxable income for home owners is understated by the sum of net rent, mortgage interest, and property taxes.

(time). If the generating process for the dependent variable has a constant mean and variance and successive observations are uncorrelated, then the sample mean is an unbiased estimator of the process mean. If these two conditions are met, then the process which generates regional median selling price can be considered stable over time. Obviously, this is not the case; examination of the data shows a definite upward trend in regional selling price over time. A moving average model is therefore not theoretically suitable for this application. A least squares regression with a linear specification would account for a trend over time; however, it would not account for a rate of change of trend, which is also apparent from the data. We therefore conclude that our model is preferable, for technical and theoretical reasons, to Almon lag, moving average, and linear least squares models.

More than 50 percent of the states have some provision for either the total or partial exemption of military income from state income taxes. Even in those states where military income is not exempt, the tax amounts actually paid by military families are generally quite small; therefore the state tax benefits due to home ownership are considered negligible in this study. Refer to All States Income Tax Guide, (1978), Office of the Staff Judge Advocate, Headquarters U.S. Air Force, Washington, D.C., and Sharff, L. and Gordon, S. Uniformed Services Almanac, by the authors, 1978.
Following Rosen, Laidler, Aaron, et al., we estimated the federal income tax benefit to home owners by calculating the following: 7

\[ f = \frac{m(rV + T)}{rV + T + D + M} \]

where:
- \( f \) = Federal tax benefit
- \( m \) = Marginal tax rate 8
- \( V_t \) = Balance on home loan, year \( t \)
- \( r \) = Mortgage interest rate
- \( T \) = Property tax (effective rate \( \times V_t \))
- \( D \) = Depreciation (straight-line from purchase price)
- \( M \) = Maintenance

7 If the home owner were taxed like other investors, he would have to report as income the gross imputed rent on his house. Like other investors, he would be allowed deductions for maintenance, depreciation, interest and property taxes as expenses incurred in earning this income. The difference between gross imputed rent and these expenses, net rent, would be included in taxable income if owner-occupied housing were treated like other investments. However, the home owner does not have to include gross imputed rent on his tax return, although he is permitted deductions for mortgage interest and property taxes. Thus, taxable income for home owners is understated by the sum of net rent, mortgage interest, and property taxes. The higher one's marginal tax rate, the greater the tax saving associated with this reduction in taxable income. See Rosen, H. S. "Housing Decisions and the U.S. Income Tax," *Journal of Public Economics* 11 (1979), 1-23, for further details.

8 We compute the marginal tax rate in a manner suggested by M. Feldstein and C. Clodfelter in their paper, "Tax Incentives and Charitable Contributions in the United States," *Journal of Public Economics* 5 (1976), 1-26. However, we make the additional assumptions that: (1) all home owners in our sample itemized deductions, and (2) total itemized deductions equal the standard deduction plus the mortgage interest rate and the property tax. Obviously, total itemized deductions need only exceed the standard deduction to make itemizing advantageous to the taxpayer. Given that it is generally advantageous for a home owner to itemize, we have two possible deviant cases: (1) If the itemized deductions other than mortgage interest and property tax are less than the standard deduction, our computed marginal tax rate would be too high. (2) If the reverse situation occurred, the computed marginal tax rate would be too low. Our method assumes that these possible deviant cases either balance out in the aggregate or are negligible.
The cost components for each observation of home ownership must be converted to a uniform series to be used as an imputed rent comparable to the rents for military and private rental observations. This conversion can be accomplished by using standard techniques associated with the time value of money. The discount rate is assumed to be an opportunity cost of the use of money assets, and is therefore defined simply as the mortgage interest rate at the time of housing choice.

We can convert the cash flow for a home over the period of ownership to a uniform monthly series with the following equation.\footnote{See Grant, E. L. and Ireson, W. G., Principles of Engineering Economy, Ronald Press Co., New York, 1970, for details.}

\[
x_{1(h)} = \sum_{h=1}^{m} I_h \left[ \frac{r(1+r)^n}{(1+r)^n - 1} \right] - \sum_{j=1}^{n/12} T_j (1 + 12r)^{-j}
\]

\[
\left[ \frac{r(1+r)^n}{(1+r)^n - 1} \right] + \sum_{k=1}^{p} M_k = \sum_{i=1}^{p} S_i \left[ \frac{r}{(1+r)^n - 1} \right]
\]

where:
1. \(x_{1(h)}\) is the uniform monthly imputed rent associated with home ownership,
2. \(r\) is the monthly discount rate,
3. \(n\) is the number of months of ownership,
4. \(I_h\) = initial cash amounts at time zero,
5. \(T_j\) = annual cash amounts due to income and property taxes,
6. \(M_k\) = monthly cash amounts, and
7. \(S_i\) = cash amounts at the time the home is sold.
8. Note that cash outflows are positive and receipts are negative.
We are now ready to discuss cost differences. Consistent with conventional economic theory, we define the relevant cost as the difference between the value of $x_i$ for the selected dwelling unit and the value of $x_j$ for a rejected dwelling unit in an alternative sector. Thus, we have $(x_{i1} - x_{j1})$ as the relevant cost of the selected dwelling unit relative to a rejected dwelling unit in an alternative sector, where the second subscript indicates housing sector.

In addition to the imputed rent for a selected dwelling unit, we therefore need $x_{ij}$ values which correspond to each family's rejected dwelling unit in each of the alternative housing sectors. For a family in a rental dwelling unit, we estimate the cost associated with a rejected owner-occupied dwelling unit as the mean of actual monthly payments for families with the same socioeconomic characteristics who actually selected home ownership.\(^{10}\) Means were calculated for families according to field

\(^{10}\) The use of total monthly payment as the cost of rejected home ownership assumes that renters perceive a higher cost for home ownership than the imputed rent perceived by home owners. There are at least two reasonable rationalizations for this assumption. First, our data shows that over 80 percent of private renters and over 66 percent of military renters are junior enlisted families with relatively low military incomes. Low income families are likely to be more concerned with meeting the higher total monthly payment than with the imputed rent, which incorporates the long-term tax benefit and capital gain. Home owners, on the other hand, tend to have higher military incomes and are better able to meet the higher monthly payment, with the expectation that the tax benefit and the capital gain will result in a lower uniform imputed monthly rent over the long term. Our second rationalization begins with Table 5 and the associated discussion. Table 5 implies the existence of a distribution of expectations with regard to the appreciation rate of owner-occupied dwelling units. If renters tend to be pessimistic with regard to appreciation rates, they would be concentrated at the low end of the distribution. The perceived cost of rejected home ownership would therefore be higher for renters compared to the imputed rent perceived by the relatively more optimistic home owners. Unlike our first rationalization, we have no hard evidence to support this second rationalization; we therefore leave the clarification to further research.
grade, company grade, senior enlisted, and junior enlisted categories at each installation included in this study. To estimate $x_{1j}$ for a rejected private rental dwelling unit, we used the mean imputed rent for private rentals for each category for each installation. The $x_{1j}$ for a rejected military rental dwelling unit is simply the BAQ to which each family is entitled.

We are now ready to consider $x_2$, the distance from a dwelling unit to the place of work for the military member of each family. For selected dwelling units, the value for distance-to-work is directly available for each observation included in this study. However, we also need valued for $x_2$ which correspond to the rejected dwelling unit in each of the alternative housing sectors. We address our method for estimating $x_2$ for these rejected alternatives in the following two paragraphs.

If we assume that comparable units for sale and for rent are available at any given distance from work, then the distance of rejected private rental (ownership) to one who chooses ownership (private rental) is identical to the observed (chosen) distance. Thus, distance does not characterize these two alternatives, except in relation to military rental.

To obtain the cost of rejected home ownership in terms of total monthly cost, we divide our home owner data into field grade, company grade, senior enlisted, and junior enlisted categories, and found mean values of the actual monthly payment for home ownership for each category. These means were used as the values for the cost of home ownership as a rejected alternative for families in each category. Note that these categories correspond very closely to income classes, from highest (field grade) to lowest (junior enlisted). A similar procedure was used to estimate values for the cost of private rental as a rejected alternative for similar reasons. We present empirical support for our opportunity cost measures in Chapter VII. More extensive models were not considered.
Alternatively, if we do not assume that comparable units for sale and for rent are available at all distances, then we may have a distinct value for the distances of the rejected private housing alternative. If the real housing market conforms with the first assumption, we will simply not get a significant coefficient on the distance variable. We use the second method, since it is more flexible. For the distance of the rejected private dwelling unit, we therefore resort to the data on families who have chosen private rental (ownership) and calculate a mean distance from the work center for each military rank at each installation.

The value of the distance variable for rejected military rental housing is simply the distance from the geometric center of the military housing complex to the work center.

We are now ready to consider \( x_3 \), the number of bedrooms in a given dwelling unit. For dwelling units that were selected, we have the value for the number of bedrooms for each observation. However, we also need values for \( x_3 \) which correspond to rejected dwelling units in each of the alternative housing sectors. To obtain rejected values for \( x_3 \), we refer to the fact that the DoD calculates a standard (median) number of bedrooms for each family size. The actual number of bedrooms for the selected housing alternative was compared to the standard which is the assumed value of the rejected alternative in each case.

We have now completed our discussion of variables \( x_1, x_2, \) and \( x_3 \). We end this section by including a discussion of variables \( y_1 \) through \( y_3 \).

As indicated in Chapter 1, \( y_1 \) is the income received by the military member of each family in our sample of individual family
observations. This income, or Regular Military Compensation (RMC), is defined as the sum of basic pay, quarters and subsistence allowance, and the tax advantage to the tax exempt status of the allowance. The tax advantage is calculated by determining the amount of additional taxable earnings required to pay the tax and still be left with the same take-home income. Thus, $y_1$ does not include income from other than DoD sources.\footnote{Following Li, et al., we attempted to include a proxy for wealth in our logit model. Unfortunately, all feasible proxies showed strong correlations to $y_1$ when incorporated in our logit regression. In fact, the interaction between income and wealth resulted in a negative coefficient for the income variable, which is inconsistent both with economic theory and the findings of previous researchers. Our wealth proxy was therefore dropped from our analysis. Wealth from sources other than military income must therefore enter the model through the error term.}

We have values for $y_2$, the number of persons in each family, for our entire sample of individual family observations.

However, our values for $y_3$, the expected period of dwelling unit occupancy, are a mix of directly observed and average values. We explain as follows. The expected periods of dwelling unit occupancy ($y_3$) were directly available for all observations of home owners; however, we had to estimate $y_3$ for families who selected private rental and military rental dwelling units. Essentially, we obtained average (mean) values for the actual period of occupancy for renters who departed each installation included in this study during the year 1978. For each rank and installation, we assume that we have no significant difference between the expected period of occupancy for private and military renters and the mean of actual periods of occupancy for
private and military renters with the same rank who departed from these installations during 1978.

**Theoretical Model**

We are now ready to present an appropriate model which can be used to theoretically and statistically explain a given military family's choice of housing sector. Consider the following framework.

First, home ownership, private rental, and military rental housing sectors represent mutually exclusive choices for a given family. For example, a family that chooses home ownership rejects private rental and military rental housing. Thus, the probabilities associated with selecting a dwelling unit from the alternative sectors sum to one. Given the probabilistic nature of the choice between housing sectors, there are two relevant types of models which could be used: a linear probability model or a model which incorporates a cumulative probability distribution. The rationale for choosing the latter is as follows.

When a linear probability model is used for prediction, two serious weaknesses of the model become apparent. First, the model involves the interpretation of predicted values of the dependent variable as probabilities, and predicted values outside the (0,1) range are possible. A less than satisfactory solution to this problem is to set extreme predicted values to either 0 or 1. While the estimation procedure might yield unbiased estimates, the predictions obtained from the estimation process are clearly biased. The second weakness arises because observations in a given sample may be drawn excessively from attributes whose values are associated with extreme values of choice probabilities (0 and 1), i.e., the attribute values may be bunched such that the estimated regression
line may significantly deviate from the true regression line.\footnote{12}

All the difficulties associated with the linear probability model point to the need for an alternative model specification. Since the most serious weakness arises from the fact that predictions may lie outside the \((0,1)\) interval, it is natural to search for alternative distributional assumptions for which all predictions must lie between \((0,1)\). This requirement suggests that the use of a cumulative probability function will provide a suitable monotonic transformation of unconstructed real independent variables to achieve a probability which ranges between \((0,1)\).

The logit model is based on the cumulative logistical probability distribution, satisfies the transformation requirement, and is therefore theoretically superior to the linear probability model. Thus, we present a three choice logit model in the following section. However, for initial runs, probit was used to minimize computer expenses.\footnote{13}

We are now ready to adopt a logit to our problem of choice. We begin with a general discussion of qualitative choice behavior and in step-by-step fashion, we develop a three choice logit model which can

\footnote{12} See Pindyck, R. S. and Rubinfeld, D. L., \textit{Econometric Models and Economic Forecasts}, 1976, Chapter 8, for further details.

\footnote{13} Probit is based on the cumulative normal probability distribution and is therefore more appealing than the linear probability model. However, probit has theoretical limitations which are not present in the logit model. See Pindyck, R. S., and Rubinfeld, D. L., \textit{Econometric Models and Economic Forecasts}, McGraw-Hill, New York, 1976, pp. 243-249, for details. We therefore used probit for our initial computer runs to work the errors out of the data base (probit is less expensive than logit), but we use logit to estimate parameters for our analysis.
be applied to an analysis of choice between the three alternative housing sectors available to military families.

Following Lancaster's approach to the theory of utility maximization, we assume that a family, acting as a decision unit, can rank-order dwelling units according to preference. The family will then choose the sector which offers the dwelling unit that maximizes its utility, as conditioned by the socioeconomic characteristics listed in Table 2. Utility is assumed to be derived from the amounts of relevant attributes inherent in each dwelling unit.14

Now consider a universe of conceivable housing attributes and let M be an arbitrary index set naming the elements of this universe. For each housing alternative, a row vector X of attributes x from M can be

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14 Lancaster, Kelvin J., "A New Approach to Consumer Theory," *Journal of Political Economy*, April 1966, also R. H. Strotz, "The Empirical Implications of a Utility Tree," *Econometrica*, 27, 1959. Lancaster recognized that the utility of a commodity is no more than the utility it yields during consumption. A commodity can be represented by a "package" of attributes which are experienced by the consumer. Thus, different housing units may offer different quantities of each relevant attribute. Strotz developed a utility tree concept which grouped commodities according to function. A household is assumed to allocate its income to commodity groups such as food, education, etc., and the to commodities within each group. The household utility function can then be expressed as

\[
U = U_1(Z_1, Z_2, \ldots, Z_a), U_2(Z_{a+1}, Z_{a+2}, \ldots, Z_b) \ldots
\]

where

- U is the level of housing utility
- \(U_j\) is the level of utility from the jth commodity group, \(j = 1, 2, 3, \ldots m\).
- \(Z_i\) is the quantity of the ith commodity, \(i = 1, 2, 3, \ldots n\).

Substitutes for commodities are found within the same groups, while independent commodities are found in separate groups. Thus, the utility derived from housing can be considered as a separate entity from the utility derived from other commodities.
observed. Referring to the set of attributes listed in Table 2, M contains three attributes as elements: monthly cost \((x_1)\), distance-to-work \((x_2)\), and number of bedrooms \((x_3)\). Each therefore includes values for \(x_1\), \(x_2\), and \(x_3\).

Consider another vector, \(Y\), which summarizes the socioeconomic characteristics of a given family. The vector \(Y\) is also defined as a row vector, and includes income, family size, etc. (See Table 2.) Thus, a family housing choice situation is also defined by a vector \(Y\) of observable socioeconomic characteristics in addition to our list of housing alternatives, each with an observable vector of attributes. Referring to the set of characteristics listed in Table 2, \(Y\) has three characteristics as elements: \(y_1\), \(y_2\), and \(y_3\).

A military family is assumed to have to choose a dwelling unit from one housing sector from among three alternative sectors identified by a vector of indices \(N = (1, 2, 3)\). Thus, the set of row vectors of the observable housing attributes available to a family can be denoted \(X = (X_1, X_2, X_3)\), where each \(X_i\) represents a row vector of values for the attributes from M. The vector observable data for a housing choice situation for a single family is then \((X, Y)\), or with subscripts identified \((X_1, X_2, X_3, Y)\). McFadden's following three axioms provide the basic structure of possible outcomes of a housing choice situation.\(^{15}\)

Axiom 1. The universe of possible outcomes is a class \(\mu\) of non-empty finite vectors of elements of M. If \(N\) identifies distinct vectors

of observed elements from $\mu$ such that a vector $X_1$ represents a possible sector choice, then $X_1$ is a possible outcome and $Y_{X_1} = Y_N$.

There are unobservable attributes of each housing alternative and unobservable socioeconomic characteristics for a given military family. Consequently, if one could obtain a sample of outcomes of housing choice situations with the same observable data $(X,Y)$ one would expect to observe an empirical distribution of choice which could be interpreted as a sample from a multinomial distribution. The selection in this multinomial distribution for an alternative $X_1$, where $(X,Y) = (X_1, X_2, X_j, Y)$ is denoted $P(X_1|X,Y)$. Note that this probability does not depend on the indexing of dwelling unit alternatives.

Our family is now ready to choose a dwelling unit from one of our three alternative sectors: (1) home ownership, (2) private rental, or (3) military rental. Thus, $N$ becomes a three element set, $N = \{1,2,3\}$. The probability of selection of alternative one becomes

$$p_1 = P(X_1|X_1, X_2, X_3, Y) = p_1^{(1)}$$

A decision rule, or demand function, is a mapping $h$ from outcomes of a family housing decision, described by data $(X,Y)$ into selected alternatives; $h(X,Y) = X$ states that a dwelling unit alternative with observable attributes $X$ is selected in a decision described by $(X,Y)$. In the presence of unobservable effects $\xi$, the decision rule $h$ will

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$^{16}$As a consequence, two housing alternatives having the same observable attributes are equally probable. This is simply an implication of the indexing system.
depend on $\xi$; we write $h_\xi(X, Y) = X$.\(^{17}\) Associated with the class of outcomes for a given family having observable data $(X, Y)$ is a probability distribution $\pi$ of the observable effects $\xi$.\(^{18}\) Then,

$$P(X_i | X, Y) = \pi(\{\xi | h_\xi(X, Y) = X_i \}).$$  

(2)

It is often convenient to suppress $\xi$ and think of $\pi$ as a probability distribution over the set of decisions rules:

$$P(X_i | X, Y) = \pi(\{h(X, Y) = X_i \}).$$  

(3)

This relation provides two possible routes to the construction of econometric qualitative choice models. The first is to assume $\pi$ to be a member of a parametric family of probability distributions over decision rules. The second is to work directly with the selection probabilities, imposing axioms which are consistent with a plausible distribution $\pi$ and which lead to convenient parametric forms for estimation. Both approaches lead to a parametric family of multinomial distributions which can be analyzed using a variety of statistical

\(^{17}\) To the extent that the effect $\xi$ arises from the practical inability of the econometrician to measure attributes of housing that are observable, we can interpret choices as coming from a deterministic choice model with observation error. Alternatively, if $\xi$ arises from factors such as loss of information by the decision maker, taste variations, or other "states of nature" that are unobservable, we can interpret the model as one of stochastic choice. In practice, it is difficult to distinguish these alternatives, particularly since "observability" varies with the application.

\(^{18}\) The form of $\pi$ depends on the mechanism used to select housing attributes. If a random mechanism is used, then $\pi$ is the conditional probability for $\xi$ given $(x, y)$. 
procedures, such as maximum likelihood.

Following McFadden, we impose conditions directly on the selection probabilities. It is convenient to use McFadden's abbreviated notation of equation (1) in stating these conditions.

**Axiom 2.** Selection probabilities are positive, i.e.,

\[ n \in N \in \mu \text{ implies } p_n(n) > 0, n = 1, 2, 3. \]

**Axiom 3.** If \( n \in N \in \xi \), then

\[ p_1p_N(2, 3) = p_2p_N(1, 3) = p_3p_N(1, 2). \]  \hspace{1cm} (4)

Since zero probability events are empirically indistinguishable from extremely unlikely events, Axiom 2 represents virtually no loss of generality. On the other hand, Axiom 3 is an extremely strong condition which implies independence from irrelevant alternatives. When \( p_N(2, 3) \) is positive, this axiom implies that \( p_{2,3} \) is positive for alternative 1, which in turn implies that

\[ \frac{p_1}{p_2, p_3} = \frac{p_N(1)}{p_N(2, 3)}, \text{ etc.} \] \hspace{1cm} (5)

This condition implies that in a choice situation \( N \) containing all three alternatives \( N = 1, 2, 3 \), the sum of the probabilities of choosing alternatives 1 or 2 or 3 equals 1.

Let us now return to the concept that a military family will maximize utility, subject to constraints, when it chooses between alternative housing sectors. A military family is assumed to have a utility function which measures the desirability of the best preferred
dwelling unit in each of the three sectors, i.e.,

\[ U = U(X, Y) = U(X_1, X_2, X_3, Y). \]  \hspace{1cm} (6)

The family will choose the first housing sector if that dwelling unit maximizes the family's utility,

\[ U(X_1, Y) > U(X_j, Y), \ j = 2, 3. \]  \hspace{1cm} (7)

If vectors \( X \) and \( Y \) completely identify a given military family's housing preferences, the behavior of this family could be predicted. In actual practice, \( X \) and \( Y \) do not represent all factors which influence the family's choice of housing. However, if the behavior of a large population of families who have the same \( Y \) vector and face the same three housing alternatives could be observed, the probabilities of the three choices for a given family could be calculated (Axiom 1). In addition, if the aggregate behavior of a large number of families from this population could be observed, these calculated probabilities would provide the best estimate of the proportion of the population that would choose each of the three sectors. 19

Equation (7) can now be written as

\[ U = U(X_1, X_2, X_3, Y, \xi) \]  \hspace{1cm} (8)

where \( \xi \) is an error vector which contains all the attributes of the best preferred dwelling units in each of the alternative sectors and

19 The concepts for the above formulation of the logit model are based on an unpublished paper by Dr. M. A. Ghali, "Multi-Purpose Version of the Paper on Multinomial Logit Model," University of Hawaii, May 1974.
characteristics of the family which cannot be measured. Provided that samples are drawn randomly from a given population of families with common socioeconomic characteristics, the vector $\xi$ will be stochastic. The random utility function $U(X_1, X_2, X_3, \xi)$ can now be written as the sum of a nonstochastic function $V(X_1, X_2, X_3, Y)$ and a stochastic term $\xi$ which is an interpretation consistent with axioms 1, 2, and 3:

$$U = U(X_1, X_2, X_3, Y, \xi) = V(X_1, X_2, X_3, Y) + \xi$$

(9)

The first housing sector will be preferred to all other housing sectors if:

$$V(X_1, Y) + \xi_1 > V(X_j, Y) + \xi_j, \quad j = 2, 3$$

(10)

or alternatively,

$$\xi_2 - \xi_1 < V_1 - V_2 \text{ and } \xi_3 - \xi_1 < V_1 - V_3$$

(11)

The family will choose housing sector 1 with some probability which can be identified by $P_1$, where

$$P_1 = \text{Prob}[V(X_1, Y) + \xi_1 > V(X_j, Y) + \xi_j]$$

$$= \text{Prob}[\xi_j - \xi_1 < V(X_1, Y) - V(X_j, Y)], \quad j = 2, 3$$

(12)

If the stochastic term $\xi_j - \xi_1$ has a cumulative distribution function $G$ and if the function $V(X_1, X_2, X_3, Y) = V(X_1, Y) - V(X_j, Y)$, $j = 2, 3$, then

$$P_1 = G[V(X_1, Y) + \xi_1 - V(X_j, Y) + \xi_j], \quad j = 2, 3$$

(13)

To estimate the probability of choosing housing sector 1, the
form of the utility function and the form of the cumulative distribution function G must be known. At this point, we assume that the utility function is linear in parameters, either directly or by an appropriate transformation of the variables $x_j$.

Now consider the form of the distribution function G. Suppose that the stochastic terms $\xi_1$, $\xi_2$, and $\xi_3$ are jointly distributed with some cumulative distribution such that the probability that $\xi_1$, $\xi_2$, and $\xi_3$ assume values $w_1$, $w_2$, and $w_3$ respectively, is given by $\Psi(w_1, w_2, w_3)$. The joint cumulative distribution function of the stochastic terms $\xi_2$, $\xi_3$, given a particular value of $\xi_1 = t$, is given by

$$\Psi_1(t, \xi_2, \xi_3)$$

(14)

where $\Psi_1$ is the partial derivative of the joint cumulative distribution function with respect to $\xi_1$. Referring to equation (10), if $\xi_1$ assumes certain value $t$, housing alternative 1 will be selected only if

$$\xi_j \leq t + V_1 - V_j, \ j = 2, 3$$

(15)

where $V_1 = V(x_1, y)$. Thus, the probability that housing sector 1 will be selected for a certain value of $\xi_1 = t$ is:

$$\Psi_1 \left[ t + V_1 - V_2, \ (t + V_1 - V_3) \right]$$

(16)

The probability of choosing sector 1 is the integral of this function for all possible values of $t$:

$$P_1 = \int_{t=-\infty}^{\infty} \Psi_1 \left[ t + (V_1 - V_2), \ (t + V_1 - V_3) \right] dt$$

(17)

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20 Ghali, op. cit.
McFadden\textsuperscript{21} has shown that with a mild technical condition, a necessary and sufficient condition for selection probabilities to satisfy equation (17) and to have the strict utility forms of equations which follow in (20), is that $\xi_1$, $\xi_2$, and $\xi_3$ be independently identically distributed with the Weibull distribution.

$$\text{Prob } (\xi_j \leq \lambda) = e^{-\lambda_j}$$ \hspace{1cm} (18)

where $-\infty \leq \lambda \leq \infty$. The joint cumulative distribution function will be

$$\sum_{j=1}^{3} e^{-\lambda_j}$$ \hspace{1cm} (19)

With the exponential distribution, equation (17) reduces to

$$p_1 = \frac{e^{\lambda_1}}{e^{\lambda_1} + e^{\lambda_2} + e^{\lambda_3}}$$

$$p_2 = \frac{e^{\lambda_2}}{e^{\lambda_1} + e^{\lambda_2} + e^{\lambda_3}}$$

$$p_3 = \frac{e^{\lambda_3}}{e^{\lambda_1} + e^{\lambda_2} + e^{\lambda_3}}$$ \hspace{1cm} (20)

Furthermore, the natural logarithms of the odds in favor of each housing alternative can be expressed as

Recall that $V_j = V_j(X_j, Y)$, $j = 1, 2, 3$, so for a vector $Y$ of socioeconomic characteristics for a given family, the natural logarithms of the ratio of the probabilities of one housing sector compared to another is simply the difference between the corresponding elements in the respective vectors $X_j$ of housing attributes for the best preferred dwelling unit in each sector. However, to obtain elasticities of the probability of choice with respect to the variation in elements of the vector $Y$, we now include observations of housing sector choice by $k$ families with different values for the elements in $Y$. Thus, for $k$ families, we have vectors $Y_k$, $k = 1, 2, \ldots, n$.

With respect to the probabilities of choice, we can now write equation (21) as follows:

\[
\log \frac{p_1}{p_2} = \alpha_{12} + \beta_{12}(x_1 - x_2) + \delta_{12}y
\]

\[
\log \frac{p_1}{p_3} = \alpha_{13} + \beta_{13}(x_1 - x_3) + \delta_{13}y
\]

\[
\log \frac{p_2}{p_3} = \alpha_{23} + \beta_{23}(x_2 - x_3) + \delta_{23}y \tag{22}
\]
where the $\beta$ and $\delta$ are $(3 \times 1)$ row vectors and the $X$ and $Y$ are $(1 \times 3)$ column vectors.\footnote{As we discussed earlier, the differences $(X_1 - X_2)$, $(X_1 - X_3)$, and $(X_2 - X_3)$ represent the differences between the respective attributes of the selected and the rejected housing sectors for a given family. The $\delta_{ij}$ are obtained by measuring the differences between the respective socioeconomic characteristics across families.}

Each equation presumes that the logarithm of the odds of one choice relative to a second choice is a linear function of the differences between the elements of the attribute vector $X$ and the characteristic vector $Y$. These odds are dependent on the odds associated with the remaining two equations only in the sense that the system must be constrained to that the sum of the individual probability equals 1. It is unnecessary to estimate each of the three equations separately, since the parameters of the third equation can be calculated once the parameters of the first two equations are known, the third equation need not be estimated.\footnote{Pindyck and Rubenfeld, op. cit.}

To conclude this section, the multinomial logit model is consistent with a theory of utility maximization by military families, with unobservable factors entering the housing utility calculus. These factors may be due to "stochastic" choice by families arising from lack of complete information on housing alternatives, or may be due to the inability of the econometrician to measure all of the variables considered by a sample of military families from a given population. We are now ready to present our empirical model and to discuss the
expected signs of the coefficients for the x and y variables identified in Table 2.

**Empirical Model and Expected Signs**

To approximate the theoretical model expressed in equation (22), we refer to a computer program developed by John G. Cragg at the University of British Columbia.\(^{24}\) Cragg's program produces maximum likelihood estimates of the parameters associated with the independent variables in equation (23). Also, the program provides asymptotic standard errors, t-ratios, correlation coefficients, and finally some summary and goodness-of-fit statistics.

As applied to our model of housing choice, Cragg's program converts to the following empirical equation:

\[
\frac{P_{\lambda}}{P_m} = \alpha_{\lambda m} + \beta_1(x_{1\lambda} - x_{1m}) \\
+ \beta_2(x_{2\lambda} - x_{2m}) + \beta_3(x_{3\lambda} - x_{3m}) \\
+ \beta_3(x_{3\lambda} - x_{3m}) + \delta_1y_1 \\
+ \delta_2y_2 + \delta_3y_3 + \mu \tag{23}
\]

where \(\lambda = 1, 2; m = 2, 3\), the \(\hat{\beta}\) are the estimated coefficients associated with the differences between the respective attributes of the selected and the rejected housing sectors; the \(\hat{\delta}\) are the estimated coefficients.

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\(^{24}\)See Cragg, John G. *Programs for Multiple Probit and Logit Analysis*, unpublished paper, Department of Economics, University of British Columbia.
coefficients associated with the respective socioeconomic characteristics across families; and \( \mu \) is the error term. Finally, we note that the Cragg program employs the Goldfeld, Quandt, and Trotter method (1966) to solve the maximum likelihood equations.\(^{25}\)

We are now ready to briefly discuss our expectations concerning the signs of the coefficients for relevant cost. Essentially, we expect a negative relationship between \( \frac{P_1}{P_2} \) and the cost difference \( (x_{11} - x_{12}) \). If \( (x_{11} - x_{12}) \) is positive, then as the difference gets smaller, the probability of home ownership will increase. On the other hand, if \( (x_{11} - x_{12}) \) is negative, then the probability of home ownership will continue to increase as the difference becomes more negative. We expect similar relationships between \( \frac{P_1}{P_3} \) and \( (x_{11} - x_{13}) \) and \( \frac{P_2}{P_3} \) and \( (x_{12} - x_{13}) \).

Now consider distance-to-work. Essentially, we expect a negative relationship between \( \frac{P_1}{P_2} \) and \( (x_{21} - x_{22}) \), since a reduction in the travel cost associated with home ownership relative to private rental would increase the probability of ownership. We expect negative relationships between \( \frac{P_1}{P_3} \) and \( (x_{21} - x_{23}) \) and \( \frac{P_2}{P_3} \) and \( (x_{22} - x_{23}) \), since military rental dwelling units are invariably closer to the work center, and as distance increases, private housing becomes less attractive in terms of increased travel costs between the dwelling unit and the work center.

For number-of-bedrooms, we expect a positive relationship between \( \frac{P_1}{P_2} \) and \( (x_{31} - x_{32}) \), since an increase in the number of bedrooms for an owned dwelling unit relative to the number of bedrooms for a private rental unit would tend to make home ownership more attractive.

\(^{25}\) Cragg, op. cit.
For $P_1/P_3$, we expect a positive coefficient for the number-of-bedrooms. Again, an increase in the number of bedrooms for an owned dwelling unit relative to military rental would tend to make home ownership more attractive.

For $P_2/P_3$, we expect a negative coefficient for number-of-bedrooms. Further, we expect a strong correlation between the cost difference and number-of-bedrooms. We explain as follows. Essentially, the monthly cost of a private rental unit, both to the landlord and subsequently to the renter, is directly related to the amount of floor space. This relationship is especially true for multi-family dwellings. However, the monthly cost of a military rental unit is constant for a given family, regardless of the number of bedrooms. Thus, as the number of bedrooms increases, the military rental unit becomes relatively more attractive in terms of the strongly correlated monthly cost.

Now consider military income ($y_1$), the first of our socioeconomic variables. Following Li, et al., we expect a clear indication that the probability of home ownership increases with respect to $y_1$. However, we expect that $P_2/P_3$ decreases with respect to $y_1$. We base our expectation with regard to $P_2/P_3$ on observations that newer and larger military dwelling units are generally reserved for senior enlisted and field grade families at the installations included in this study. There is a direct relationship between rank and military income, therefore as military income increases, so does the incentive to obtain military rental housing. In the absence of capital gain and tax benefit incentives, private rental would therefore appear to be the least attractive alternative for higher income military families.
We are now ready to provide a framework for our test of whether the probability of home ownership increases or decreases as a function of family size, holding income constant.

We begin with a brief summary of Li's findings. Initially, as family size increases with income held constant, Li hypothesized that larger families substitute housing service for non-housing goods. However, as family size continues to increase with income held constant, the largest families substitute non-housing goods for housing service. Li then analyzed a representative sample of private rental and owner occupied dwelling units and concluded that owner occupied units provide more housing service in terms of floor space per dollar spent than private rentals. Thus, with income held constant, Li expected the conditional probability of home ownership to initially rise with increases in family size but to eventually decline for the largest families. Li's empirical results tended to support his hypothesis.

Given Li's plausible explanation of the relationship between housing choice and family size, we hypothesize that the conditional probability of home ownership compared to private rental tends to increase with military family size, holding income constant. We also expect to observe a leveling off effect for the largest families, and possibly a decrease.

However, military families also have the military rental option. As we previously explained and Li's work tends to support, larger families initially substitute housing service for non-housing goods. Further, a larger family may well demand more housing service than

provided by the standard military dwelling unit to which they are
nominally entitled. Thus, we expect that the probability of choosing
a private dwelling unit increases as family size increases. However,
we also expect a leveling off effect and possibly a decrease in this
probability for the largest families for reasons analogous to Li's
explanation concerning the probability of home ownership.

We are now ready to discuss the expected signs for the coefficient
of $y_3$, the expected period of occupancy, relative to our conditional
probabilities. Essentially, we expect that both $P_1/P_2$ and $P_1/P_3$ will
increase as a function of $y_3$ because the expected capital gain and the
tax benefit associated with home ownership increase over time, making
home ownership relatively more attractive over the long run. However,
we have no a priori reason to suppose that $P_2/P_3$ will either increase
or decrease as a function of $y_3$. We therefore expect that $y_3$ will not
be significant in this case.

We have now concluded our discussion of our empirical model and
the expected signs of the coefficients associated with the $x$ and $y$
variables listed in Table 2. Our estimated demand functions, using
data from Travis, Ellsworth, MacDill, and Tinker Air Force bases and
our empirical results concerning the interaction of income and family
size, are presented in Chapter VII. In the following chapter, we
present a model which permits us to evaluate the current DoD housing
program in terms of social benefits and social costs.
IV. MILITARY RENTAL HOUSING COMPARED TO PRIVATE HOUSING: A BENEFIT-COST MODEL

Introduction

In this chapter, we are concerned with the benefits and costs of military rental housing compared to private market alternatives. Our purpose is to determine whether the current DoD housing program is economic according to the criterion that social benefits exceed social costs.¹

As stated in Chapter I, we define net family benefit as the difference between the benefits and costs which accrue directly to a given family that exclusively consumes a given amount of military rental housing service. We define net social benefit as the social benefits minus social costs associated with the fact that a given family exclusively consumes a given amount of military rental housing service. Net family benefit is therefore a subset of net social benefit; however, as we explain in detail later, we assume that all relevant benefits and costs accrue either to families who consume military rental housing

¹There are several alternative criteria for evaluating the current DoD housing program compared to the private market. For example, we could: (1) minimize the DoD cost of inducing all military families to consume at least the DoD standard amount of housing service, or (2) maximize DoD benefits minus costs. However, in this chapter, we limit our analysis to evaluating the DoD program according to the criterion identified above.
service or to the DoD.  

We limit our analysis to two DoD policy options for military families grouped according to field grade, company grade, senior enlisted, and junior enlisted categories. The first option is the current DoD program of providing military rental housing to families in a given category at rents equal to each family's Basic Allowance for Quarters (BAQ). The second option is a program which provides no military rental housing to families in a given category, but as an alternative, provides a cash increase in BAQ for each family in that category equal to the average (mean) net family benefit for that category. We are now ready to summarize the remaining sections of this chapter.

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2Given freedom of choice between military rental and private housing alternatives, a family that voluntarily chooses military rental will not experience a net cost compared to the private market. However, society may experience a net cost even though the family experiences a net benefit.

3A possible third policy option is for the DoD to provide cash grants restricted to the purchase of housing service. It is possible that such a cash grant would be smaller than the unrestricted cash grant necessary to induce a family to voluntarily choose at least the equivalent amount of private housing service. We discussed this alternative with responsible officials at Headquarters U.S. Air Force, Directorate of Engineering and Services, Housing and Services Division. The DoD has not used restricted cash grants for housing in the past because of the administrative cost and the possible adverse reaction of military members to perceived restrictions on their consumer sovereignty. For these reasons, we believe that a program of restricted cash grants in addition to current BAQ or a program of totally restricted BAQ are not likely alternatives for the future. We therefore do not include restricted cash grant programs in our analysis. Other alternative programs were not considered.
Overview

In the following section on theory, we first define the term "housing service." We then state our assumptions. Finally, we provide a framework for our theoretical model.

In the fourth section, we present our theoretical model. First, our model provides a method for estimating net family benefit for each of our four military family categories. Second, our model provides a method for estimating the mean net social benefit per family or alternatively, the mean net social cost per family for each of our four categories. We use this second aspect of our model to set the framework for a test of our hypothesis that the DoD has an economic justification for providing military rental housing service according to the criterion that social benefits exceed social costs. We show that if we have a mean net social benefit per family in a given category, then the DoD has an economic justification for providing housing service to each family in that category. On the other hand, if we find a mean net social cost per family, then society would be better off and each family no worse off on the average, if the DoD gave each family in that category a cash grant equal to the average net family benefit for that category. As a final theoretical point, our categories of field grade, company grade, senior enlisted, and junior enlisted families correspond very closely to income classes, from highest to lowest. In a limited sense, our model therefore offers a means of explaining the variation in benefits as a function of income.

In the fifth and final section of this chapter, we provide an empirical model consistent with the theory presented in the previous
sections. We also discuss the empirical measurement of the variables used in our model. The results of an application of our empirical model are presented in Chapter VII.

Theory

In this section, we define the term housing service, state our assumptions, and set the framework for our theoretical model.

First, consider the term "housing service." Following Muth, Olsen, et al., housing service is an unobservable good emitted in some quantity by each dwelling unit during each period of time. It is the one and only thing in a dwelling unit to which consumers attach value. Intuitively, the quantity of housing service emitted by a dwelling unit can be thought of as an index of both quantitative and qualitative attributes.

For the purpose of this chapter, we measure all dwelling units in terms of homogeneous housing service units. Apparent differences between housing service units in owner-occupied, private rental, and military rental sectors are resolved by using imputed rents. Thus,

We have an apparent difference between owner-occupied and private rental housing service because owner-occupied dwelling units are joint investment consumption alternatives whereas private rental units are strictly consumption alternatives. We resolve this apparent difference by imputing a monthly rent for each owner-occupied dwelling unit. To obtain an imputed rent from the negative monthly cash flow experienced by a family that occupies an owned dwelling unit, we subtract discounted monthly amounts for both the expected net capital appreciation over the expected period of occupancy, and the annual income tax benefit, and we add the foregone interest on the actual down payment.

Likewise, we have an apparent difference between military rental and private rental housing service because the rental for military rental dwelling units are arbitrarily determined by the DoD, not by a perfectly competitive private market. Again, we resolve this apparent difference by imputing a monthly rent for each military dwelling
we can say that in equilibrium on a monthly basis, an owner-occupied unit with an imputed rent of $400 yields twice the housing service compared to an owner-occupied unit with an imputed rent of $200 or a private rental unit with a rent of $200 or finally, a military rental unit with an imputed rent of $200. Now consider the following assumptions which concern military rental housing.

First, we assume that at each installation included in this study, dwelling units are standardized for all families within each of our four categories. We make this assumption in light of the following empirical evidence.

At each installation, we observed that the total floor space per dwelling unit is essentially constant for all dwelling units in each category. Also, the major appliances are almost invariably the same type, brand, and model for all dwelling units within each category. Also, all dwelling units within each category have access to approximately the same yard space, and finally, all dwelling units, regardless of category, have a uniform off-white paint on interior walls.

We also observed minor differences between dwelling units in some categories at each installation. Specifically, we noted minor differences in floor plans to accommodate different size families.

To obtain an imputed rent, we assume that the monthly expenditure for a military dwelling unit on the private market would be the same as the average monthly rent for private rental units or the average monthly imputed rent for owner-occupied units with the same physical attributes. Using cost proxies for physical attributes, we use regression techniques to obtain an equation which permits a prediction of the imputed rent for each military dwelling unit. We discuss our method in more detail later in this chapter.
Also, there are minor differences in the colors of exterior paint. Of course, we also observed minor differences due to dwelling unit location within housing tracts. However, for the purpose of this study, we consider these minor differences to be negligible within categories, and the dwelling units within each category at each installation are sufficiently alike to be considered standardized.

Now consider our second and final assumption for military rental housing. Essentially, we assume that the standard dwelling unit in each category described above represents the DoD standard amount of housing service units for each family within that category.

We are now ready to state our assumptions about private housing markets. Consider private housing markets in communities adjacent to military installations. Throughout this analysis, we assume that perfectly competitive conditions prevail in these markets, and in addition, we assume that military families are free to move from military rental to private housing in response to market conditions. The assumption of perfect competition is consistent with previous studies by Muth (1960), deLeeuw and Ekanem (1971), et al. The freedom of movement assumption is consistent with empirical conditions at all military installations examined during this study. Further, information concerning prices and corresponding amounts of housing service are readily available to military families through housing referral offices located on each military installation.

Now we are ready to discuss our assumptions concerning benefits and costs. Even at the individual family level, a comprehensive benefit-cost analysis of DoD provided military rental housing service would include all benefits and costs which accrue to all economic
entities in society that are affected by the fact that a given family consumes a given amount of military rental housing service. A list of those affected would include: the family itself, the DoD, local governments, landlords, real estate firms, home builders and sellers, consumers of private housing service, businesses which provide non-housing goods and services, public utilities, and local and federal taxpayers. However, we simplify our measurement problem by assuming that except for the benefits and costs which accrue to the family and the costs which accrue to the DoD, all other benefits and costs are either negligible in themselves or would tend to balance out to a negligible net amount. We are now ready to set the framework for our model, which considers the benefits and costs consistent with our assumptions.

Consider a family that has chosen military rental as opposed to private housing. Since our hypothetical family had the option of living in private housing, military rental must make them better off. There is some amount of money X that would have made the family indifferent to the following two alternatives: (1) living in military rental housing during some time period (say an entire tour of duty at given military installation), or (2) accepting an unrestricted cash grant of X dollars on the stipulation that they live in private housing during the same time period. If we were to offer the family a cash grant of more than X for the given period they would accept; if

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Note that we assume that the DoD experiences no benefits, only costs, for providing military rental housing. This is not precisely true, since the DoD may experience some benefits due to the externalities which may be associated with having an exclusively military community on the installation itself. Our study is therefore limited in that we do not consider these possible benefits in our analysis.
we offered an amount less than X, they would reject the offer. Following Bish and Olsen, we define X dollars to be the net direct benefit of military rental housing service to our hypothetical family. We are now in a position to approximate net family benefit in terms of consumer surplus.  

Theoretical Model

As stated in Chapter III, military families have a choice between three housing sectors: military rental, private rental, or homeownership. We now provide a method for estimating the net family benefit of military rental housing compared to the private sectors with the help of a simple theoretical model.

To begin, we note that there are only three alternative housing consumption patterns associated with military families that choose to exclusively consume military rental housing service. For the first two alternatives, a family may choose to consume more housing service compared to private market alternatives. It may consume at a point on or below its housing service (quantity variable) demand curve, or it may consume at a point above its demand curve but at a price below the price of the same amount of housing service in the private market. As a third alternative, a family may choose to consume less housing service compared to private market alternatives; in which case it will consume

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at a point below its demand curve. We clarify these alternative consumption patterns with the following indifference curve analysis.

Consider Figure 1, where the price of private housing service is reflected in budget line LM and the price of military rental housing service is reflected in budget line LN. $Q_{J1}$ and $Q_{J2}$ represent two attainable amounts of military rental housing service on utility level $U_1$ and $Q_H$ represents an amount of private housing service which corresponds to a point on the family's housing service (quantity variable) demand curve. The amount $Q_H$ also represents the family's best housing alternative in the private market.

Along utility level $U_1$, our family would be indifferent between military rental housing service $Q_{J1}$ and $Q_{J2}$ and private housing service $Q_H$. However, by geometry we know that our family may choose any available amount of military rental housing service between $Q_{J1}$ and $Q_{J2}$ and be on a higher level of utility compared to $Q_H$ and $U_1$.

Figure 1. Utility Space and the Demand for Housing Service.
Of the $Q_J$ between $Q_{J1}$ and $Q_{J2}$, only the amount of housing service associated with the point $D'$ corresponds to a point on the family's housing service demand curve. Point $F'$ corresponds to a point which is below the demand curve. At point $F'$, $Q_J > Q_H$. Point $G'$ corresponds to a point which is above the demand curve but below the price of the same amount of private housing service. Again, $Q_J > Q_H$. Finally, point $K'$ corresponds to a point below the demand curve, but $Q_J < Q_H$. Points $D'$, $F'$, $G'$, and $K'$ represent the only feasible consumption patterns relevant to military families, given our assumptions of freedom of choice and of perfect competition in the private housing market. To further our analysis, we now consider three conventional demand curve diagrams where points $F$, $G$, and $K$ correspond to points $F'$, $G'$, and $K'$, respectively, in Figure 1.

Figure 2 illustrates military housing consumption at point $F$. Our hypothetical family has chosen to consume more military housing service compared to its next best private market alternative, which is illustrated by point $A$. In Figure 2 and the subsequent discussion, we have:

$$Q_J = \text{The amount of military rental housing service to which a given family is nominally entitled.}$$

$$P_J = \text{Price per unit of } Q_J.$$

$$Q_H = \text{Amount of private housing service (either rental or owned) which corresponds to a point on an individual family's demand curve and which represents the family's next best alternative in the private market.}^{7}$$

$$P_H = \text{Price per unit of } Q_H,$$

and finally,

---

$^{7}$The amount $P_H Q_H$ corresponds to the uniform monthly rent or imputed rent for private dwelling units that we developed in Chapter III.
\[ D_i = \text{Individual family demand curve for housing service.} \]

Private housing service consumption as a second choice would have occurred at \( Q_H \), for which the outlay would have been \( P_H Q_H \). However, our hypothetical family has actually chosen military housing at \( Q_J \) for an outlay of \( P_J Q_J \), where \( Q_J \) is greater, in this illustration, than the private alternative by the amount \( Q_J - Q_H \).

\[
\begin{align*}
\text{P} & \quad \text{A} \quad \text{B} \\
\text{P_H} & \quad \text{E} \quad \text{C} \\
\text{P_J} & \quad \text{F} \\
\text{0} & \quad \text{Q_H} \quad \text{Q_J} \\
\text{Q} & \quad \text{(Housing Service)} \\
\end{align*}
\]

Figure 2. Housing consumption pattern where the selected amount of military rental housing service is greater than the private housing alternative, and point \( F \) is below the demand curve.

The market value of this increase in housing consumption is

\[ 8\text{In this model, the demand curve is drawn as if money income were held constant when the price of housing was changed. To be completely correct, a decrease in the price of housing with money income unchanged could also lead to an increase in the purchase of housing service as the result of the increase in real income. Thus, a demand curve with the increase in real income taken into account would be more elastic than a demand curve with real income held constant. See Friedman, Price Theory, Chicago, Aldine Publishing Company, 1962.} \]
However, as perceived by the family, \( Q_{HABQ} \) is an overestimate of net benefit due to an increase in housing service by the amount of the triangle ABC and the cost to the family of the additional housing service.\(^9\) The net benefit to the family due to an increase in housing service is therefore \( Q_{HACQ} - Q_{HEFO} \).

Now consider the fact that this hypothetical family also has more income available to spend on non-housing goods.\(^11\) To be precise, a family with total income \( I \) that occupies a military rental unit consumes \( P_{PH} Q_{PH} - P_{QJ} Q_{QJ} \) more non-housing goods than they would have on the private rental market.

Net family benefit \( X \) is equal to the excess in consumer surplus at point F compared to the consumer surplus at point A. Mathematically,

\[
X = P_{PH} Q_{PH} + \int_{Q_{PH}}^{Q_{QJ}} DdQ - P_{QJ} Q_{QJ} \tag{1}
\]

\(^9\)Note that in a perfectly competitive market, the supply curve faced by each family is perfectly elastic at price \( P_{PH} \). On the other hand, military housing supply is a point at F which is consistent with the fact that the amount of military housing service and the price are determined by rank, not by market conditions.

\(^10\)In his study of public housing, Bish (1960, op. cit.) includes area ABC as part of the value of the benefit which accrues directly to the tenant of a public housing unit. However, we choose to let ABC represent a dead weight loss, which is consistent with traditional consumer surplus theory.

\(^11\)A comparatively lower price for military rental housing service may induce a family to buy (1) more military rental housing service, (2) more non-housing goods, or (3) more of both, depending on the income elasticities, etc. We analyze that most general case, which permits the increase in purchase of both to be positive or zero.
Finally, we note that the net benefit of the military rental option to the family whose housing situation is depicted in Figure 1 can be thought of as the sum of (1) the net benefit derived from spending more money on non-housing service.

We now consider a housing consumption pattern where \( Q_J > Q_H \), but consumption occurs at point \( G \). Using the same notation as in Figure 2, Figure 3 illustrates military housing consumption at point \( G \), which is compared to the family's next best private housing alternative at point \( A \). As in Figure 2, private housing consumption as a second

![Figure 3. Housing service consumption pattern with the selected amount of military rental housing service greater than the private market alternative, and point \( G \) is above the demand curve.](image)

choice would have occurred at \( Q_H \), for which the outlay would have been \( P_H Q_H \). Again, our family has actually chosen military housing at \( Q_J \) for an outlay of \( P_J Q_J \), where \( Q_J \) is greater than the private alternative by \( Q_J - Q_H \). However, we now have a difference compared to Figure 2 because point \( G \) is above the demand curve.

We now explore the implications for our model of this difference.
Consider the amounts of housing service \((Q_H' - Q_J')\) and \((Q_J' - Q_J)\) separately. For the amount of housing service between \(Q_H\) and \(Q_J'\), we have a net benefit to the family equal to \((Q_H'ADQ_J'\) minus \(Q_H'EDQ_J')\), which is consistent with Figure 2. Added to the increase in benefit due to an increase in consumption of nonhousing goods, we have a net benefit equal to \((OP_H'ADQ_J'\) minus \(OP_JEDQ_J')\), which is the excess in consumer surplus at point D compared to point A. For the amount between \(Q_J'\) and \(Q_J\), the additional outlay is \(Q_J'DGCQ_J\). However, the perceived benefit is only \(Q_J'DCQ_J\). The additional outlay exceeds the perceived benefit by an amount equal to area DGC. Thus, area DGC must be subtracted from \((OP_H'ADQ_J'\) minus \(OP_JEDQ_J')\) to obtain a correct measure of net family benefit for consumption at point G compared to consumption at point A. At this point, we can easily show that \((OP_H'ADQ_J'\) minus \(OP_JEDQ_J'\) minus DGC) is measured precisely by equation (1). We therefore conclude that our model expressed in equation (1) also accommodates the housing consumption pattern illustrated in Figure 3.

Now consider a housing consumption pattern where \(Q_J < Q_H\), and consumption occurs at point K. In Figure 4, private housing consumption as a second choice would have occurred at \(Q_H\), for which the outlay would have been \(PHQ_H\). Again, our family has actually chosen military housing at \(Q_J\) for an outlay of \(P_JQ_J\). However, in this case \(Q_J < Q_H\). Given the assumption that our family could have moved to private housing if it had chosen to do so, the only incentive they had for choosing military rental is that \(P_JQ_J\) permits them to consume a sufficiently greater amount of non-housing goods to offset the smaller consumption of housing service.
In the case depicted in Figure 4, our family consumes $P_H Q_H - P_H Q_J$ less housing service than they would have in the private rental market. The market value of this decrease in housing consumption is $Q_JBAQ_H$. However, as perceived by the military family, $Q_JBAQ_H$ is an underestimate of the value of the decrease in housing service by the amount of the triangle ABC. The net loss to the family due to a decrease in housing service is therefore $Q_JCAQ_H$.

On the other hand, if our hypothetical family chooses military housing at $P_J Q_J$, they consume $P_H Q_H - P_J Q_J$ more non-housing goods.

As depicted in Figure 4, the net family benefit $X$ is equal to the excess in consumer surplus at point $K$ compared to the consumer surplus at point $A$, or

$$X = P_H Q_H - \int_{Q_J}^{Q_H} DdQ - P_J Q_J$$

By reversing the limits and changing the sign on the integral, one could show that equation (2) is precisely equal to equation (1).
Intuitively, the net benefit of the military rental option to the family whose housing situation is depicted in Figure 4 can be thought of as the algebraic sum of (1) the net benefit derived from spending more money on non-housing goods, and (2) the net loss from consuming less housing service.

We are now ready to aggregate our net family benefit estimates according to field grade, company grade, senior enlisted, and junior enlisted categories. From these aggregate amounts, we can determine the net benefit for the average family in each category. We begin with equation (3).

\[ \bar{X}_h = \frac{1}{n} \sum_{i=1}^{n} X_i \]  

(3)

where \( \bar{X}_h \) is the average net family benefit per family for category \( h \), \( h = 1, 2, 3, \) and \( 4 \), and \( X_i \), which corresponds to \( X \) in equations (1) and (2), is the net benefit for family \( i \) in category \( h \), \( i = 1, 2, 3 \ldots n \).

Now that we have an equation for determining the average net family benefit, we consider the additional cost to the DoD of providing a given amount of housing service to a military family. We then present equations to estimate net social and average net social benefits.

For a family in a given category, we know that the net cost to the DoD of amount \( Q_J \) is simply \( (AC_M - P_J)Q_J \), where \( AC_M \) is the average cost per unit of housing service to the DoD. We also note that \( AC_M \) is determined exogeneously from the model presented above.\(^{12}\) Thus, given

\(^{12}\)Values of \( AC_M \) for each category and installation in this study
our assumptions concerning all other costs and benefits associated with military rental housing, the net social benefit of \( Q_J \) for family \( i \) in category \( h \) is \( X - (A_{CM} - P_J)Q_J \).\(^{13}\)

We are now ready to set the framework for a test of our hypothesis that the DoD has an economic justification for providing military rental housing to families in each of our four categories.

Essentially, if we find that we have an average (mean) net social benefit per family for a given category, then our hypothesis is true and the DoD has an economic justification for providing housing service on a voluntary basis to families in that category. If we find an average net social cost per family for a given category, our hypothesis is false and society would be better off and each family no worse off, on the average, if the DoD gave each family an unrestricted cash increase in their BAQ equal to average net family benefit for that category.

As we have defined our terms, we can say that if

\[
\frac{1}{n} \sum_{i=1}^{n} [X_i - (A_{CM} - P_J)Q_J_i] > 0
\]

\(^{(4)}\)

were obtained from Headquarters U.S. Air Force, Directorate of Engineering and Services, Housing and Services Division. These data include the interest on the construction cost debt and all operating and maintenance costs per dwelling unit for 1978. Given the assumptions of our model, inequality \((4)\) is indeed a measure of net social benefit in a consumer surplus sense. Other measures are, of course, possible.

\(^{13}\) Based on a review of the data from the installations included in this study, we conclude that the DoD may actually experience a tangible net benefit by providing housing service to military families by taking in more in terms of forfeited BAQ than they spend for maintenance, utilities, etc. We obtained average cost per dwelling unit data for field grade, company grade, senior enlisted, and junior enlisted units at Travis, Ellsworth, MacDill, and Tinker Air Force bases. There were no positive cash flows except for each family's forfeited BAQ, which
our hypothesis is true. If inequality (4) is not true, then our hypothesis is false.

**Empirical Model**

Now we convert our theoretical model into practical equations for the manipulation of available empirical data. First, consider the following summary of our theory on the net benefit of military rental housing to a given military family.

Referring to equations (1) and (2), we have:

\[
X = P_H Q_H + \int_{Q_H}^{Q_J} DdQ - P_J Q_J
\]

We need to develop an empirical equation that approximates the theoretical equation for \(X\) for family \(i\). First, we assume a simple demand equation of the form

\[
P = a - bQ,
\]

where \(a\) and \(b\) are constants. Since \(D\) is assumed to be linear, we can show that

\[
a = (P_H + bQ_H) \quad \text{and} \quad b = \frac{1}{\varepsilon} \left(\frac{P_H}{Q_H}\right),
\]

we include in our analysis. Although there may be certain intangible benefits to the DoD, we assume that these are negligible.
where $\varepsilon$ is the absolute value of the price elasticity of demand.

$$\int_{Q_H}^{Q_J} DdQ = \int_{Q_H}^{Q_J} (a - bQ) dQ,$$  \hspace{1cm} (8)

Therefore

$$\int_{Q_H}^{Q_J} DdQ = a(Q_J - Q_H) - \frac{b}{2} (Q_J - Q_H)(Q_J + Q_H)$$  \hspace{1cm} (9)

Substituting equations (6) and (7) into (9), we have,

$$\int_{Q_H}^{Q_J} DdQ = (P_H Q_J - P_H Q_H)[(1 + 1/\varepsilon) - \frac{P_H Q_J + P_H Q_H}{2\varepsilon P_H Q_H}]$$  \hspace{1cm} (10)

and finally:\footnote{Recall that in equation (5), we assumed a linear segment to our demand curve. This assumption, which simplifies our mathematics considerably, results in a positive bias to our estimate of net family benefit. However, over the price range involved, we believe this bias is negligible.}

$$X_1 = P_H Q_H + (P_H Q_J - P_H Q_H)[1 + 1/\varepsilon] - \frac{P_H Q_J + P_H Q_H}{2\varepsilon P_H Q_H} - P_J Q_J$$  \hspace{1cm} (11)

Thus, our empirical $X_1$ is a function of $P_J Q_J$, $\varepsilon$, $P_H Q_H$, and $P_H Q_J$. The amount of $P_J Q_J$ is simply a given family's expenditure per time period on military rental housing, which is precisely equal to the family's BAQ. Again, $\varepsilon$ is the price elasticity of demand for housing service. The amount $P_H Q_H$ is the cost per time period of a given family's best alternative in the private market, and finally, $P_H Q_J$ is the cost per time period in the private market of $Q_J$ housing service. The amount $P_J Q_J$ is available directly from the data. However, we must estimate
We address our method for estimating each of these variables in the following paragraphs.

Previous studies (deLeeuw, 1971, et al.) have found price elasticities ranging from -0.7 to -1.7 for rental housing and price elasticities ranging from -0.7 to -1.5 for owner-occupied housing. Since data are available, we use observations of military families to estimate our own price elasticities. Consider the following equations which express the quantity of housing service units demanded by a family as a function of the relative price of housing service units and real income.

\[
\ln\left(\frac{P_{H} Q_{H}}{P}\right) = \alpha + \beta_{1} \ln(\frac{P}{Q}) + \beta_{2} \ln(\frac{I}{Q}), \text{ (lower bound)} \tag{12}
\]

and

\[
\ln\left(\frac{P}{Q}\right) = \alpha + \beta_{3} \ln\left(\frac{P_{H} Q_{H}}{P}\right) + \beta_{4} \ln(\frac{I}{Q}), \text{ (upper bound)}
\]

where

\[
P_{H} Q_{H} = \text{Uniform monthly cost of a private sector dwelling unit, pooled home owner and private renter observations.}
\]

\[
P = \text{Regional median monthly rental cost}
\]

\[
Q = \text{Regional average cost of living (housing plus all other goods).}
\]

\[
I = \text{Monthly military income.}
\]

Thus, our estimator of price elasticity has a lower bound of \(\hat{\beta}_{1}\) and an upper bound of \(1/\hat{\beta}_{3}\).\(^{15}\)

\(^{15}\)deLeeuw developed a similar equation which also held the price of non-housing goods and money income constant and permitted the price to
We will later test the sensitivity of our subsequent estimates of average net family and average net social benefits over our range of price elasticities indicated by equation (12). Our results are discussed in Chapter VII.

Now consider a method for estimating $P_{H}Q_{H}$, the cost per time period of a given family's best alternative in the private market. For $P_{H}Q_{H}$, we follow Olsen and assume that a family in military rental housing would have spent the same amount on housing in the private market as the average expenditure on housing of military families with the same military rank who actually live in private housing. To estimate $P_{H}Q_{H}$, we therefore refer to our observations on military families in private housing.

Again, our family in military rental housing could have chosen either private rental or home ownership. We therefore pool our private rental and home owner observations. Also, we assume that our average (mean) $P_{H}Q_{H}$ for each category and installation calculated from our private market observations is a suitable approximation to the foregone

\[
\frac{P_{H}Q_{H}}{P}
\]

vary. The use of \( \frac{P_{H}Q_{H}}{P} \) as the dependent variable and \( P/Q \) as an independent variable is also consistent with deLeeuw's approach. Also, see deLeeuw for a detailed explanation of the terms "upper and lower bound" with reference to the upper and lower limits for price elasticity. Note however, that our data includes individual observations of pooled monthly housing (imputed) rents and income for private renters and owner-occupants, whereas deLeeuw used median values and estimated separate renter and home owner elasticities. We also note that our monthly imputed rents for housing services per dwelling unit for home ownership are adjusted for income tax benefit, the expected capital gain when the dwelling unit is sold at the end of the expected period of occupancy, and the foregone interest on the actual down payment. See Chapter III for details. Finally, our private renter observations of monthly cost are taken directly from survey data; each observation includes all expenses associated with private rental.
P_rO_r for military renters. Thus, we have values of P_rO_r for field
grade, company grade, senior enlisted, and junior enlisted families at
each installation included in this study.

Now consider our method for estimating P_rO_r. In his study of rent
control in New York City in 1968, Olsen assumed that a controlled
dwelling unit would rent on the uncontrolled market for the average
rent of uncontrolled units with the same physical attributes. He went
on to assume that the stochastic model that explained the differences
in rents of different uncontrolled dwelling units in New York City in
1968 was:

\[
P_rO_r = b_0 + \sum_{i=1}^{31} b_i X_i + \nu, \tag{13}
\]

where the \(X_i\) represent certain physical attributes of dwelling units.
Thus, his predictor of the uncontrolled market rent of a controlled
dwelling unit was

\[
\hat{P}_rO_r = \hat{b}_0 + \sum_{i=1}^{31} \hat{b}_i \hat{X}_i, \tag{14}
\]

where the \(\hat{b}\)'s were least squares estimates of the \(b\)'s in equation (13).

If we were to follow Olsen, we would assume that the monthly
expenditure for a military dwelling unit on the private market would be
the same as the average monthly expenditure for private rental or owner-
occupied dwelling units with the same physical attributes. However, we
do not have sufficient data on the physical attributes of either
private rental or owner-occupied units to justify using equations
similar to (13) and (14) above. We therefore use the following
alternative method.
Instead of observations which include values for physical attributes, we have observations on owner-occupied dwelling units which include the 1978 purchase price and the 1978 average monthly operating and maintenance cost. By using these cost attributes as proxies, we account for all physical attributes which influence the monthly cost of the dwelling unit in the private market.

We therefore assume that the model which explains the differences in average monthly expenditures among military families who actually purchased homes during 1978 was

\[ P_{H}Q = \delta_0 + \sum_{i=1}^{2} \delta_i Z_i + \epsilon, \epsilon \sim N(0, \sigma^2) \]  

(15)

where the \( Z_i \) are defined as follows:

- \( Z_1 \) = The 1978 selling (purchase) price of the housing unit,
- \( Z_2 \) = Average monthly operating and maintenance cost, including utilities, maintenance, and property tax during 1978.

We also assume that given a sample of \( T \) joint observations of the dependent variable and the regressors produced by the model (15), the successive disturbances \( \epsilon_t (t = 1, 2, 3, \ldots, T) \) are mutually independent and the regressors are non-stochastic. Thus, our predictor of the average monthly cost (PHQJ) for a military rental unit during 1978 is:

\[ P_{H}Q = \hat{\delta}_0 + \sum_{i=1}^{3} \hat{\delta}_i \hat{Z}_i \]  

(16)

where the \( \hat{\delta}_i \)'s are the least squares estimators of the \( \hat{\delta}_i \)'s in equation (15).

Since we want to use equation (16) to predict \( P_{H}Q \) for the military
rental-home ownership comparison, we need values for the \( Z_i \) associated with military rental housing units. First, consider the fact that military installations have traditionally built distinct housing units for four categories of military families: field grade officers, company grade officers, senior enlisted, and junior enlisted. As we stated earlier, the associated housing units within each category are physically alike, with minor variations due to location and in some cases, minor variations in floor plans and exterior paint. Thus, it is reasonable to use average values of \( Z_i \) for each category at each installation.

First, we need \( Z_1 \), the 1978 equivalent selling (purchase) price for each category of housing unit at each installation. We have actual values for construction cost, including improved land, housing appreciation rates, and the year that units in each category were built for each installation covered by this study. From these data, we now proceed to construct values for \( Z_1 \).

If we assume a perfectly competitive home owner housing market, then the cost of construction, including improved land, and a normal profit, equals the approximate selling price during the year of construction.\(^{16}\) Also, since we know that military housing units are maintained in good repair, it is reasonable to apply the housing unit appreciation rate associated with existing housing units in the

\(^{16}\)Military housing construction projects, by law and military regulation, are assigned to private contractors on a competitive bid basis. Thus, given our assumption of perfect competition, we have reasonable assurance that the average construction cost per military housing unit within each category approximates the construction cost per unit in similar tract housing developments in the adjacent civilian community.
adjacent civilian community to our military housing units. Thus, we approximate the 1978 equivalent private market selling price for field grade, company grade, senior enlisted, and junior enlisted housing units at each installation.

Now consider $Z_2$, the monthly operating and maintenance cost. For $Z_2$, we have average values per housing unit at each installation included in the study. These operating and maintenance costs include utilities and repairs, which implicitly includes the cost of self-insurance. However, we do not have property tax as a component of operating costs, since by law, Federal government property cannot be taxed by local governments. Thus, our operating and maintenance cost data for military housing units are lower than the private market equivalent by the amount of the equivalent property tax. However, we account for the equivalent property tax associated with each military housing unit by using local single family home effective tax rates multiplied by our estimated 1978 selling prices. The estimated monthly tax for each type of unit is then added, as appropriate, to make $Z_2$ for military rental dwelling units comparable to the $Z_2$ for owner-occupied units in the private market.

We have now completed our discussion of our theoretical and empirical models for evaluating the current DoD housing program in terms of net social benefits or costs. In the following chapter, we present models for evaluating the current program in terms of whether it actually achieves its stated purpose of increasing the amount of housing service consumed by military families. Again, the results for the empirical models presented in Chapters IV and V are discussed in Chapter VII.
V. MILITARY RENTAL HOUSING COMPARED TO PRIVATE HOUSING: ALTERNATE AMOUNTS OF HOUSING SERVICE CONSUMPTION

Introduction

Public Law 345 permits the Department of Defense (DoD) to increase the amounts of housing service consumed by military families if the private market does not provide amounts consistent with military incomes and with certain arbitrary DoD standards of housing service consumption.¹ Essentially, Public Law 345 provides the legal basis for the current DoD housing program.² In this chapter, we present a theoretical model which permits us to determine whether the current program induces military families in various categories to consume more or less housing service that they otherwise would in the private market.

Overview

In the following two sections, we set up our evaluation of the current DoD housing program and we present our theoretical model. Our

¹The DoD has set housing service consumption standards for families grouped according to field grade, company grade, senior enlisted, and junior enlisted categories.

²Public Law 345, August 11, 1955 amends sections 401 through 409, Title VIII, National Housing Act, June 27, 1934.
final section provides a few brief comments concerning the empirical application of our model. We abbreviate our discussion in this chapter, since our assumptions, consumer surplus analysis, and much of our procedure concerning the empirical application of our model correspond to the assumptions, analysis and procedure presented in Chapter IV.

General Theory

We are now ready to set the framework for our evaluation of the current DoD housing program. To begin, our model provides a method for estimating $Q_J$, the amount of housing service consumed by a given military family in a military rental dwelling unit, compared to $Q_H$, the amount of housing service provided by the family's next best private market alternative. Our model then provides a method for estimating mean $Q_J$ compared to a mean $Q_H$ for each of our four categories. We designate these averages as $\bar{Q}_J$ and $\bar{Q}_H$, respectively.

We are now ready to describe how we use our model to evaluate the current DoD housing program. Essentially, if our model shows that $\bar{Q}_J$ is greater than $\bar{Q}_H$, we can say that the current DoD housing program is effective with regard to the criterion set forth in Public Law 345 because the DoD has induced families in that category to consume the DoD standard amount of housing service, which is greater than the average amount provided by their respective next best private market alternatives. On the other hand, if our model shows that $\bar{Q}_J$ is less than $\bar{Q}_H$, we can say that the current DoD housing program is not effective because families in that category would, in the absence of the program, obtain a greater average amount of private housing service than the DoD
standard amount. Essentially, families that choose military rental dwelling units with \( Q_J < Q_H \) have made choices consistent with the consumption pattern described in Chapter IV, Figure 4. If \( Q_J < Q_H \) for a given category, the current DoD housing program simply permits the families in that category, on the average, to consume additional non-housing goods to the point where they experience a net benefit by choosing a military rental dwelling unit.

We are now ready to state our hypothesis. Formally, we hypothesize that \( Q_J \) is greater than \( Q_H \) for each of our four categories, and that as a consequence, the current DoD housing program, on the average, induces military families to consume more housing service than they otherwise would in the absence of the program. On the other hand, if \( Q_J \) is less than \( Q_H \) for a given category, then our hypothesis is false for that category.

**Theoretical Model**

We are now ready to present our theoretical model. Given the assumptions made in Chapter IV, we have two possible cases of housing service consumption relevant to a given family that exclusively consumes military rental housing service. These two possible cases are depicted in Figures 5(a) and 5(b) below.

In Figure 5(a), we depict a case where a family has actually chosen a military rental dwelling unit at \( Q_J \) for an outlay of \( P_J Q_J \), where \( Q_J \) is greater than the family's next best private alternative by the amount \( Q_J - Q_H \). The shaded area in the left hand side of Figure 5(a) represents the amount \( P_H Q_H - P_J Q_J \), and the shaded area on the
Figure 5. A comparison of alternative amounts of housing service consumption.

right represents the amount:

\[ p_H q_H + \int_{q_H}^{q_J} d_d q - p_J q_J \]

From Figure 5(a), we see that:

\[ [p_H q_H - p_J q_H] < [p_H q_H + \int_{q_H}^{q_J} d_d q - p_J q_J]. \]  \hspace{1cm} (1)

Thus, if inequality (1) is true for a given family that has selected a military rental dwelling unit, that family clearly consumes
more housing service than its next best private housing alternative, and \( Q_J > Q_H \).\(^3\)

Figure 5(b) illustrates the case where a family has chosen a military rental dwelling unit at \( Q_J \) for an outlay of \( P_J Q_J \), where \( Q_J \) is less than the family's next best private alternative by the amount \( Q_H - Q_J \). Applying our previous analysis to Figure 5(b), we can see that:

\[
[P_H Q_H - P_J Q_J] > [P_H Q_H - \int_{Q_J}^{Q_H} DdQ - P_J Q_J].
\]  \( (2) \)

---

\(^3\) Mathematically we can subtract \( P_H Q_H \) from both sides of inequality (1) and obtain:

\[
\int_{Q_H}^{Q_J} DdQ - P_J Q_J > -P_J Q_H.
\]

By dividing through by \( -P_J \), we obtain:

\[
Q_J - \frac{1}{P_J} \int_{Q_H}^{Q_J} DdQ > Q_H
\]

which clearly indicates that

\( Q_J > Q_H \).
Thus, if inequality (2) is true for a given family that has selected a military rental dwelling unit, that family clearly consumes less housing service than its next best private housing alternative, and \( Q_J < Q_H \). 

**Empirical Model**

We are now ready to present our model in terms of the empirical variables discussed in Chapter IV and extend our model to permit estimates of \( Q_J \) compared to \( Q_H \). First, note that the right side of inequalities (1) and (2) are both equivalent to \( X \) from equations (1) and (2) in Chapter IV. Thus, we have

\[
(P_H Q_H - P_J Q_H) < X, \quad \text{and} \quad (3)
\]

\[
(P_H Q_H - P_J Q_H) > X \quad \text{(4)}
\]

for inequalities (1) and (2) respectively.

\( P_J Q_H \) represents the cost of \( Q_H \) private housing service units at the DoD price. We can manipulate our equation to include this amount by using \( P_J Q_J \), \( P_H Q_H \), and \( P_H Q_J \), which represent BAQ, the cost of the next best private market alternative, and the cost of \( Q_J \) military rental housing service in the private market, respectively, as defined in Chapter IV. Thus, we have

\[
[P_H Q_H - \frac{(P_J Q_J)(P_H Q_H)}{P_H Q_J}] < X \quad \text{(5)}
\]

\[4\] We can easily demonstrate a mathematical proof similar to the proof demonstrated in footnote 3.
At this point, we have expressed our inequalities for an individual family that exclusively consumes military rental housing service. Following a procedure similar to our procedure in Chapter IV, we incorporate our individual family estimates for $X$, $P_H^{Q_H}$, and $P_H^{Q_J}$ and our observed values of $P_J^{Q_J}$ within the framework of (5) and (6) to determine a test of our hypothesis for each of our four categories. Specifically, we calculate values for each side of our inequality separately. We then aggregate the values for each side according to field grade, company grade, senior enlisted, and junior enlisted categories for each of the four installations included in this study. We then calculate a mean for each side, category, and installation and determine whether, on the average, military renter families in each category at each installation consume more or less housing service than they otherwise would in the private housing market.

The results of our empirical application are presented in tabular form in Chapter VII. Essentially, an entry in the table of $Q_H < Q_J$ would indicate that on the average, military renters for a given category and installation consume more housing service in the military rental sector than they would in the private market. Of course, an entry of $Q_H > Q_J$ would indicate precisely the opposite.
VI. SUMMARY OF DATA AND VARIABLES

Introduction

In this chapter, we briefly discuss the data and the variables used in this study and identify our sources. In addition, we draw distinctions between directly observed variables for individual families, average value variables, and variables which were estimated.

We begin with a summary of the observations for individual families. We then identify the directly observed and average value variables associated with home owners, private renters, and military renters, in that order. We also identify our sources. Finally, we list the variables which had estimated values.

Summary: Observations for Individual Families

The data for this study includes 1,822 observations of certain variables associated with individual military families at four Air Force installations within the continental United States. All observations are for calendar year 1978.

Table 6 identifies the 1978 population of military families who selected either: home ownership, private rental, or military rental housing at each of the four installations listed.

Table 7 identifies percent sample of the respective populations and the number of observations for each housing choice option at each of the four installations.

We now identify the sources for our individual family
### TABLE 6
MILITARY FAMILIES-1978

<table>
<thead>
<tr>
<th>Base</th>
<th>Home Owners</th>
<th>Private Renters</th>
<th>Military Renters</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ellsworth, SD</td>
<td>982</td>
<td>282</td>
<td>1879</td>
<td>3318</td>
</tr>
<tr>
<td>Tinker, OK</td>
<td>1491</td>
<td>789</td>
<td>530</td>
<td>2810</td>
</tr>
<tr>
<td>MacDill, FL</td>
<td>1858</td>
<td>657</td>
<td>803</td>
<td>3142</td>
</tr>
<tr>
<td>Travis, CA</td>
<td>1735</td>
<td>550</td>
<td>2133</td>
<td>4418</td>
</tr>
<tr>
<td>Total</td>
<td>6066</td>
<td>2278</td>
<td>5345</td>
<td>13689</td>
</tr>
</tbody>
</table>

### TABLE 7
OBSERVATIONS OF MILITARY FAMILIES AT GIVEN PERCENT SAMPLE

<table>
<thead>
<tr>
<th>Base</th>
<th>Percent Sample</th>
<th>Homeowners</th>
<th>Private Renters</th>
<th>Military Renters</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ellsworth</td>
<td>12.7</td>
<td>125</td>
<td>36</td>
<td>238</td>
<td>399</td>
</tr>
<tr>
<td>Tinker</td>
<td>19.9</td>
<td>296</td>
<td>157</td>
<td>105</td>
<td>558</td>
</tr>
<tr>
<td>MacDill</td>
<td>9.0</td>
<td>168</td>
<td>59</td>
<td>72</td>
<td>299</td>
</tr>
<tr>
<td>Travis</td>
<td>12.8</td>
<td>223</td>
<td>70</td>
<td>273</td>
<td>566</td>
</tr>
<tr>
<td>Total</td>
<td>13.4</td>
<td>812</td>
<td>322</td>
<td>688</td>
<td>1822</td>
</tr>
</tbody>
</table>

observations. First, consider the 1978 Department of Defense (DoD) Family Housing Survey. The data from this survey, provided as a magnetic computer tape, included individual family observations for all completed survey forms (DD Forms 1376, Family Housing Questionnaires) returned to all U.S. military installations that participated in the survey. Questionnaires were completed and returned by over 95 percent of all military families at each installation. Each observation was identified by the social security number of the military member of
each family. This tape was provided by Mr. Terry Trevier, Department of the Navy, Naval Facilities Engineering Command, FACSO, Port Hueneme, California.

Now consider the 1978 Family Housing Preference Survey. The data from this survey, provided as a set of returned questionnaires, included 812 observations of individual military family home owners at four Air Force installations: Travis, Ellsworth, MacDill, and Tinker. Observations from this survey were correlated with the corresponding observations from the 1978 DoD Family Housing Survey by the social security number of the military member. This correlation provided a complete set of directly observed variables for the 812 home owner observations used in this study. The questionnaire for this survey was approved by Headquarters U.S. Air Force, Directorate of Engineering Services and the Air Force Military Personnel Center. The survey was conducted specifically for this study during the fall of 1978.

Thus, by combining the data from the two surveys, we obtained a statistical sample of observations for individual military families at each of the four installations identified in the above tables. Further, by selecting four installations near urban areas in widely separated geographical regions within the continental U.S., we obtained a statistical sample of all such installations. We are now ready to consider the variables associated with each observation.

Variables Used in this Study

For each home owner observation, we obtained the following directly observed variables from the combined survey:
TABLE 8
HOME OWNER DATA
1. Purchase price of home
2. Down payment
3. Year purchased
4. Mortgage interest rate
5. Monthly principal and interest payment
6. Average total monthly payment for each family
7. Expected period of occupancy at the time of home purchase
8. Number of bedrooms
9. Distance to work
10. Military income
11. Number of persons in household

For each private renter and military renter observation, we obtained the following variables from the 1978 DoD Family Housing Survey:

TABLE 9
RENTER DATA
1. Average total monthly rental payment
2. Number of bedrooms
3. Distance to work
4. Military income
5. Number of persons in household

Now consider our average value variables. For each installation, we have the following average value variables which relate to
home ownership.

TABLE 10

HOME OWNERSHIP RELATED DATA

1. Effective property tax rate
2. Average monthly maintenance payment
3. Average monthly utility payment
4. Owner-occupied home insurance rates

Our source for average variable 1 values (effective property tax rate) for homes in communities adjacent to the installations included in this study was the City and County Databook, 1978, U.S. Department of Commerce, Bureau of the Census. Our source for the values for average variables 3 and 4 was the Statistical Abstract of the U.S., 1978, U.S. Department of Commerce, Bureau of the Census. We obtained 1978 values for average variable 4 from Ms. Norma Litherland, Actuarial Research Assistant, United Services Automobile Association, USAA Building, San Antonio, Texas.

For each installation, we have the following average variables which relate to both rental options.

TABLE 11

RENTAL VARIABLES

1. Average monthly utility payment
2. Renter occupied insurance rates
3. Average damage deposit
4. Cleaning expenses when home is vacated
5. Expected period of occupancy, by rank, for each installation.
Our source for average variable 1 (average monthly utility payment) values for communities adjacent to the military installations included in this study was the *City and County Databook, 1978*, op. cit. Again, insurance rates (average variable 2) were provided by Ms. Norma Litherland.

Values for variables 3 and 4 were obtained from the Housing Referral Offices located at Travis, Ellsworth, MacDill, and Tinker Air Force bases. Values for variable 5 were obtained from the Air Force Military Personnel Center. These values correspond almost precisely to the individual military family populations associated with the 1978 DoD Housing Survey.

Finally, we have the following average variables for military rental housing units for field grade, company grade, senior enlisted and junior enlisted categories at each installation.

**TABLE 12**

**MILITARY RENTAL HOUSING DATA**

1. Number of units built and year of construction for all units in each category

2. Construction cost per unit

3. Average DoD monthly operating and maintenance cost per unit, including debt payment

Our source for the values for these variables was: Headquarters U.S. Air Force, Directorate of Engineering and Services, Housing and Services Division, and in the case of debt payment, Air Force Regulation 178-1.

We have now completed our discussion of the data used in this study and their sources. As indicated above and in Chapters III, IV,
and V, we used certain of these data directly as variables in our study. However, in some cases, we used data to determine estimates for the variables identified in the following two tables.

**TABLE 13**

ESTIMATES RELATED TO HOME OWNERSHIP

1. Federal income tax benefit
2. Expected annual selling price appreciation rate
3. Realtor commission for selling a home (a)
4. Incidental selling expenses (b)
5. Foregone interest on down payment (c)
6. Pessimistic estimate of total monthly cost
7. Realistic estimate of total monthly cost
8. Optimistic estimate of total monthly cost
9. Price elasticity of demand for housing service
10. Wealth position of family

---

NOTES: (a) We assumed six percent of selling price.
(b) We assumed that the interest rate associated with the down payment equaled the mortgage interest rate.
(c) We assumed two percent of selling price.

**TABLE 14**

ESTIMATES RELATED TO RENTAL ALTERNATIVES

1. Price elasticity of demand for housing service
2. Average 1978 market selling price per military housing unit in each of four categories at each installation
3. Average equivalent private market monthly operating and maintenance cost per military housing unit in each of four categories at each installation
4. Normal profit to landlord for a private rental housing unit (a)
TABLE 14-Continued
ESTIMATES RELATED TO RENTAL ALTERNATIVES

5. Average equivalent private market monthly cost per military housing unit in each of four categories at each installation

NOTE: (a) Assumed to equal the mortgage interest rate times the average equivalent monthly cost if the unit were owner-occupied.

We have now completed our brief summary of data and variables used in this study. Additional details and clarification are contained in the text or in footnotes, as appropriate, in Chapters III, IV, and V.
VII. EMPIRICAL RESULTS

Introduction

In this chapter, we present and interpret the empirical results obtained from our application of the models presented in Chapters III, IV, and V. We summarize these models as follows. First, our logit model from Chapter III provides a method for explaining the effects of the current DoD housing program on military family choice of housing sector. Second, our benefit-cost model from Chapter IV provides a method for evaluating the current DoD housing program according to the criterion that social benefits exceed social costs. Finally, our housing service consumption model from Chapter V permits us to determine whether the current DoD housing program induces military families to consume more or less housing service than they otherwise would in the private housing market. All three models were applied to observations of certain independent variables associated with 1,822 military families assigned to Travis, Ellsworth, MacDill, and Tinker Air Force bases during calendar year 1978.

Overview

In the third section of this chapter which immediately follows, we provide a series of tables which present estimated logit coefficients, certain goodness-of-fit statistics, and the means and standard deviations associated with the values of our independent variables. We also present tables and figures which illustrate the probability of
home ownership as a function of family size for six income categories. We also present the probability of private rental given that a family chooses to rent as a function of family size for six income categories. Finally, we note that we accompany each table and figure with a brief interpretation of the results presented.

In the fourth section, we present the mean net social and net family benefits (costs) associated with military families grouped according to junior enlisted, senior enlisted, company grade, and field grade categories. Again we accompany our tables with a brief interpretation of the results.

In the fifth and final section of this chapter, we present and interpret the results of our test of whether the current DoD housing program induces military families to consume more or less housing service than they otherwise would in the private market. Specifically, we present a table which compares the mean amount of selected military rental housing service to the mean amount of rejected private housing service for military families grouped according to junior enlisted, senior enlisted, company grade, and field grade categories.

**Logit Analysis of Housing Choice Behavior**

Table 15 includes the estimated logit coefficients and certain goodness-of-fit statistics for the probability of home ownership compared to private rental \( \frac{P_1}{P_2} \). We interpret the results in Table 15 as follows. To begin, we note that the coefficients for relevant cost, difference in number of bedrooms, income, and expected period of occupancy are significant and have the expected signs. However, the coefficients for the difference in distance-to-work and for family size
were not significant.

TABLE 15
PROBABILITY OF HOME OWNERSHIP COMPARED TO PRIVATE RENTAL

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Logit Coefficient</th>
<th>Independent Variable</th>
<th>T-Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_1 / P_2 )</td>
<td>-0.9611 ((x_{11} - x_{12}))</td>
<td>((x_{21} - x_{22}))</td>
<td>-8.8539</td>
</tr>
<tr>
<td></td>
<td>0.0161</td>
<td>((x_{31} - x_{32}))</td>
<td>1.0279</td>
</tr>
<tr>
<td></td>
<td>1.9618</td>
<td>( y_1 )</td>
<td>9.1942</td>
</tr>
<tr>
<td></td>
<td>0.7238</td>
<td>( y_2 )</td>
<td>3.4139</td>
</tr>
<tr>
<td></td>
<td>-0.0643</td>
<td>( y_3 )</td>
<td>0.8347</td>
</tr>
<tr>
<td></td>
<td>-0.6850</td>
<td>Constant</td>
<td>-1.2597</td>
</tr>
</tbody>
</table>

Pseudo R-Square = .5160
Pseudo R-Square for Model = .7404
Likelihood Ratio Test = 822.12 with 6 D.F.

The lack of significance for the difference in distance-to-work coefficient merits further explanation. Essentially, it is possible that travel cost-to-work is the relevant variable rather than distance-to-work.\(^1\) Car pools, bus lines, and other modes of travel may effectively change travel costs so that distance is relatively unimportant. However, confirmation or denial of this possibility is left to further research.

\(^1\)We implicitly include the opportunity cost of time spend in travel as part of travel cost-to-work. Refer to Mills, Edwin S., Urban Economics, Scott, Foresman and Co., 1972, pp. 85-88. Also see the empirical studies referenced by Mills with regard to the choice of transportation mode for travel-to-work,
At this point, we find it useful to briefly compare the signs of our income and cost difference coefficients for the probability of home ownership compared to private rental equation with the signs of the income and price coefficients obtained by Ohls with his probit switching equation. Essentially, the signs of these two coefficients are the same, respectively, for both models. We can make no further comparisons due to the theoretical differences between logit and probit and the differences in model specification. Also, we cannot compare goodness-of-fit statistics, since Ohls does not present such statistics in his paper.

Table 16 provides mean and standard deviation statistics for the independent variables in our home ownership compared to private rental logit run. Of special interest are the mean values for the monthly cost difference (measured in dollars), and the mean values for the distance differences (measured in miles).

TABLE 16
VARIABLE STATISTICS FOR HOME OWNERSHIP TO PRIVATE RENTAL COMPARISON

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home owner cost difference</td>
<td>-46.95</td>
<td>113.60</td>
</tr>
<tr>
<td>Private rental cost difference</td>
<td>-31.88</td>
<td>73.24</td>
</tr>
<tr>
<td>Home owner distance difference</td>
<td>1.43</td>
<td>.73</td>
</tr>
<tr>
<td>Private rental distance difference</td>
<td>-.59</td>
<td>3.37</td>
</tr>
<tr>
<td>Home owner bedroom difference</td>
<td>.06</td>
<td>.96</td>
</tr>
<tr>
<td>Private rental bedroom difference</td>
<td>-.06</td>
<td>.96</td>
</tr>
<tr>
<td>Income (RMC)</td>
<td>18430.00</td>
<td>7949.00</td>
</tr>
</tbody>
</table>
TABLE 16-Continued
VARIABLE STATISTICS FOR HOME OWNERSHIP TO
PRIVATE RENTAL COMPARISON

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of persons in family</td>
<td>3.71</td>
<td>2.13</td>
</tr>
<tr>
<td>Expected period of occupancy</td>
<td>46.26</td>
<td>17.28</td>
</tr>
</tbody>
</table>

Table 17 contains our logit coefficients and goodness-of-fit statistics for the probability of home ownership compared to military rental \(P_1/P_3\). We interpret the coefficients presented in Table 17 as follows. First, with the exception of distance, all coefficients are significant and have the expected signs. Again, we refer to Mills and to the possibility of specification error with regard to the distance variable. We also point out that the negative coefficient for the family size variable is not conclusive with regard to our test of the probability of home ownership as a function of family size, since we placed no restrictions on the variation of income across families. We discuss our test of the probability of home ownership with regard to family size later in this chapter.
TABLE 17
PROBABILITY OF HOME OWNERSHIP COMPARED TO MILITARY RENTAL

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Logit Coefficient</th>
<th>Independent Variable</th>
<th>T-Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_1/P_3$</td>
<td>-2.2423</td>
<td>$(x_{11} - x_{13})$</td>
<td>-19.2048</td>
</tr>
<tr>
<td></td>
<td>0.0824</td>
<td>$(x_{21} - x_{23})$</td>
<td>3.7084</td>
</tr>
<tr>
<td></td>
<td>0.8545</td>
<td>$(x_{31} - x_{33})$</td>
<td>4.9057</td>
</tr>
<tr>
<td></td>
<td>0.4682</td>
<td>$y_1$</td>
<td>2.8612</td>
</tr>
<tr>
<td></td>
<td>-0.1280</td>
<td>$y_2$</td>
<td>-3.1523</td>
</tr>
<tr>
<td></td>
<td>0.0204</td>
<td>$y_3$</td>
<td>2.2918</td>
</tr>
<tr>
<td></td>
<td>0.9575</td>
<td>Constant</td>
<td>2.2191</td>
</tr>
</tbody>
</table>

Pseudo R-Square = 0.5895
Pseudo R-Square for Model = 0.7876
Likelihood Ratio Test = 1331.04 with 6 D.F.

Table 18 provides mean and standard deviation statistics for the independent variables in our home ownership compared to military rental logit run.
TABLE 18
VARIABLE STATISTICS FOR HOME OWNERSHIP TO MILITARY RENTAL COMPARISON

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home owner cost difference</td>
<td>-1.30</td>
<td>78.15</td>
</tr>
<tr>
<td>Military renter cost difference</td>
<td>-108.20</td>
<td>130.05</td>
</tr>
<tr>
<td>Home owner distance difference</td>
<td>6.06</td>
<td>7.90</td>
</tr>
<tr>
<td>Military renter distance difference</td>
<td>-4.44</td>
<td>5.19</td>
</tr>
<tr>
<td>Home owner bedroom difference</td>
<td>0.32</td>
<td>.66</td>
</tr>
<tr>
<td>Military renter bedroom difference</td>
<td>-.32</td>
<td>.67</td>
</tr>
<tr>
<td>Income (RMC)</td>
<td>19700.00</td>
<td>7258.00</td>
</tr>
<tr>
<td>Number of persons in family</td>
<td>4.04</td>
<td>1.92</td>
</tr>
<tr>
<td>Expected period of occupancy</td>
<td>47.22</td>
<td>15.15</td>
</tr>
</tbody>
</table>

The following table presents the logit coefficients and goodness-of-fit statistics for the probability of private rental compared to military rental ($P_2/P_3$). The cost difference coefficient is significant and has the expected sign. The difference in distance-to-work coefficient is not significant for reasons postulated earlier. The difference in number-of-bedrooms coefficient is significant, has the expected sign, and has a strong positive correlation (.469) to the cost difference.
TABLE 19

PROBABILITY OF PRIVATE RENTAL COMPARED TO MILITARY RENTAL

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Logit Coefficient</th>
<th>Independent Variable</th>
<th>T-Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_2/P_3$</td>
<td>-0.5154</td>
<td>$(x_{12} - x_{13})$</td>
<td>-3.4818</td>
</tr>
<tr>
<td></td>
<td>-0.0141</td>
<td>$(x_{22} - x_{23})$</td>
<td>-0.8004</td>
</tr>
<tr>
<td></td>
<td>-1.2850</td>
<td>$(x_{32} - x_{33})$</td>
<td>-7.3724</td>
</tr>
<tr>
<td></td>
<td>-0.6238</td>
<td>$y_1$</td>
<td>-2.8752</td>
</tr>
<tr>
<td></td>
<td>-0.4196</td>
<td>$y_2$</td>
<td>-4.1425</td>
</tr>
<tr>
<td></td>
<td>-0.0290</td>
<td>$y_3$</td>
<td>2.2384</td>
</tr>
<tr>
<td></td>
<td>2.8002</td>
<td>Constant</td>
<td>4.0865</td>
</tr>
</tbody>
</table>

Pseudo R-Square = .3839
Pseudo R-Square for Model = .5380
Likelihood Ratio Test = 489.21 with 6 D.F.

Table 20 provides mean and standard deviation statistics for the independent variables in our private rental compared to military rental logit run. Of special interest is the fact that the mean cost difference for private renters is a positive number.
TABLE 20

VARIABLE STATISTICS FOR PRIVATE RENTAL TO MILITARY RENTAL COMPARISON

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private renter cost difference</td>
<td>24.27</td>
<td>54.38</td>
</tr>
<tr>
<td>Military renter cost difference</td>
<td>-111.70</td>
<td>115.20</td>
</tr>
<tr>
<td>Private renter distance difference</td>
<td>2.40</td>
<td>3.80</td>
</tr>
<tr>
<td>Military renter distance difference</td>
<td>-6.54</td>
<td>5.10</td>
</tr>
<tr>
<td>Private renter bedroom difference</td>
<td>-.20</td>
<td>.86</td>
</tr>
<tr>
<td>Military renter bedroom difference</td>
<td>.20</td>
<td>.86</td>
</tr>
<tr>
<td>Income (RMC)</td>
<td>16080.00</td>
<td>6989.00</td>
</tr>
<tr>
<td>Number of persons in family</td>
<td>3.66</td>
<td>1.31</td>
</tr>
<tr>
<td>Expected period of occupancy</td>
<td>47.42</td>
<td>3.67</td>
</tr>
</tbody>
</table>

A further inspection of the data provided some interesting evidence with regard to the characteristics of families that live in private rental and military rental housing. Essentially, we found that approximately 80 percent of the private renters in our representative sample are junior enlisted families. On the other hand, 23 percent of the home owners and 66 percent of the military renters were junior enlisted. The percent of junior enlisted families in military rental is consistent with the respective percentage of the total population at the installations included in this study. However, junior enlisted families are under-represented in the home owner sector and over-represented in the private renter sector.

There are at least two possible explanations consistent with the above evidence. First, it is likely that many junior enlisted families experience wealth and budget constraints which limit their
entry in the home ownership sector and are effectively limited to the private rental and the military rental sectors. Given the constraints to home ownership, it is possible that they pay a premium to live in private rental rather than military rental housing because they perceive a positive difference in the amount of housing service provided by private rental dwelling units compared to the military rental dwelling unit offered. This explanation would incorporate possible perceived negative externalities associated with living on the installation in a military environment. A second possible explanation includes wealth and budget constraints to home ownership but involves a different explanation of the private rental premium relative to military rental. Essentially, it is possible that junior enlisted families experience effective barriers to the military rental sector which are not experienced by families with higher ranking military members. For example, junior enlisted families that are technically eligible for military rental housing may lack seniority on waiting lists or may have relatively less information and experience with regard to obtaining the military rental option. We leave confirmation or denial of these two and other possible explanations to future research.

We are now ready to discuss our expectations with regard to our analysis of the probability of home ownership as a function of family

---

Many studies have shown that the cash flow problem represents a substantial barrier to home ownership for lower income, less wealthy families. For example, see Miller, G.H., "The Affordability of Ownership in the 1970s," Economic Review, Federal Bank of Kansas City, September-October 1980.
size, holding income constant. Consider military families in the private market. Consistent with the findings of Li, we expect that the conditional probability of home ownership will increase and then decline as family size increases, holding income constant.\(^3\) However, military families also have the military rental option. Essentially, we expect that the probability of choosing a private dwelling unit will increase and then decline as family size increases because larger families are able to obtain larger dwelling units in the private market compared to the standard unit offered by the DoD. Finally, we expect a leveling-off and possibly a decrease in the probability of choosing a private dwelling unit for the largest families for reasons analogous to Li's explanation concerning the probability of home ownership with respect to private rental.

The results of our analysis are presented in Tables 21 and 22 and Figures 6 through 11. Table 21 presents the conditional probability of home ownership given that a family has selected private housing. Table 22 provides the conditional probability of home ownership given that a family may select either home ownership, private rental, or military

\(^3\)See Li, op. cit., also see Quigley, op. cit. for additional evidence. Essentially, Quigley has shown that holding income constant, larger families are less likely to choose multi-family units and are more likely to choose common-wall and single detached units. Further, Quigley has shown that for income classes beginning with $5,000–$7,000, larger families have a higher probability of consuming progressively larger effective lot sizes. An inspection of the private housing data available for our study shows that multi-family dwelling units are overwhelmingly private rental units. Also, common-wall units (including duplexes and townhouses) have a greater proportion of owner-occupancy compared to multi-family units, and single detached dwelling units are predominately owner-occupied. Given that larger families tend to choose common-wall and single detached units, we would therefore expect the probability of home ownership to increase with family size,
rental housing. Each table shows the respective probabilities as a function of family size for six income classes. We graph the probabilities from Tables 21 and 22 in Figures 6 through 11, where \( P(1/1,2) \) represents the probability of home ownership (1) given the choice of private housing (1,2), and \( P(1/1,2,3) \) represents the probability of home ownership given the choice of home ownership (1), private rental (2), or military rental housing (3). Our findings with regard to \( P(1/1,2) \) are consistent with Li, and our findings with regard to \( P(1/1,2,3) \) clearly indicate the effect of the military rental option on the choice of housing sector as a function of family size.
### TABLE 21

**CONDITIONAL PROBABILITY OF HOME OWNERSHIP**  
**GIVEN THAT A FAMILY CHOOSES**  
**PRIVATE HOUSING P(1/1,2)**

<table>
<thead>
<tr>
<th>Income Class</th>
<th>Family Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>$7,000 - 9,999</td>
<td>2</td>
</tr>
<tr>
<td>.192</td>
<td>.388</td>
</tr>
<tr>
<td>10,000 - 14,999</td>
<td>.643</td>
</tr>
<tr>
<td>15,000 - 19,999</td>
<td>.600</td>
</tr>
<tr>
<td>20,000 - 24,999</td>
<td>.895</td>
</tr>
<tr>
<td>25,000 - 29,999</td>
<td>.900</td>
</tr>
<tr>
<td>30,000 - 37,000</td>
<td>.929</td>
</tr>
</tbody>
</table>

### TABLE 22

**PROBABILITY OF HOME OWNERSHIP**  
**P(1/1,2,3)**

<table>
<thead>
<tr>
<th>Income Class</th>
<th>Family Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>$7,000 - 9,999</td>
<td>2</td>
</tr>
<tr>
<td>.171</td>
<td>.271</td>
</tr>
<tr>
<td>10,000 - 14,999</td>
<td>.353</td>
</tr>
<tr>
<td>15,000 - 19,999</td>
<td>.300</td>
</tr>
<tr>
<td>20,000 - 24,999</td>
<td>.723</td>
</tr>
<tr>
<td>25,000 - 29,999</td>
<td>.642</td>
</tr>
<tr>
<td>30,000 - 37,000</td>
<td>.591</td>
</tr>
</tbody>
</table>
Figure 6. 7,000-9,999 Income

Figure 7. 10,000-14,999 Income

Figure 8. 15,000-19,999 Income

Figure 9. 20,000-24,999 Income

Figure 10. 25,000-29,999 Income

Figure 11. 30,000-37,000 Income
We now turn to our analysis of $P(2/2,3)$, the conditional probability of choosing private rental, given that a family has chosen to rent. Essentially, we stated in Chapter III that we expected $P(2/2,3)$ to increase and then decrease as family size increased, holding income constant. Our empirical results are presented in the following table, and in Figures 12 through 17.

**Table 23**

<table>
<thead>
<tr>
<th>Income Class</th>
<th>2</th>
<th>3-4</th>
<th>5</th>
<th>6+</th>
</tr>
</thead>
<tbody>
<tr>
<td>$7,000 - 9,999$</td>
<td>.871</td>
<td>.508</td>
<td>.217</td>
<td>.167</td>
</tr>
<tr>
<td>$10,000 - 14,999$</td>
<td>.303</td>
<td>.112</td>
<td>.131</td>
<td>.235</td>
</tr>
<tr>
<td>$15,000 - 19,999$</td>
<td>.286</td>
<td>.078</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$20,000 - 24,999$</td>
<td>.692</td>
<td>.195</td>
<td>0</td>
<td>.125</td>
</tr>
<tr>
<td>$25,000 - 29,999$</td>
<td>.200</td>
<td>.100</td>
<td>0</td>
<td>.333</td>
</tr>
<tr>
<td>$30,000 - 37,000$</td>
<td>.111</td>
<td>.048</td>
<td>.120</td>
<td>0</td>
</tr>
</tbody>
</table>
Figure 12. 7,000-9,999 Income

Figure 13. 10,000-14,999 Income

Figure 14. 15,000-19,999 Income

Figure 15. 20,000-24,999 Income

Figure 16. 25,000-29,999 Income

Figure 17. 30,000-37,000 Income
Clearly, as family size increases for a given income class, the conditional probability of private rental, given that a family rents, drops rapidly then increases slightly. This result is not consistent with the expectation given in Chapter III.

We offer the following explanation. First, as we stated earlier, the monthly cost of private rental dwelling units increases directly with the amount of floor space. Second, military rental dwelling units have a standard monthly cost (forfeited BAQ) which is independent of the amount of floor space offered. If military rental dwelling units are relatively large to begin with and if military families become more concerned with floor space as family size increases, then military families would tend to select military rental dwelling units with more floor space per rental dollar compared to private rental. Under these conditions, we would observe a decrease in the conditional probability of private rental as family size increases.\textsuperscript{4} Other possible explanations are left to further research.

This concludes our presentation and interpretation of the results obtained from our analysis of military family choice of housing sector. In the following section, we present the results obtained from our benefit-cost model.

\textsuperscript{4}Given that we observe a consistent decrease $P(2/2,3)$ for all income classes, we infer that the DoD provides larger dwelling units. A detailed confirmation or denial of this inference is beyond the scope of this paper. However, the opinion that it is a correct inference is shared by the responsible base housing officials at the installations included in this study.
**Net Social and Net Family Benefits of Military Rental Housing**

In Table 24, we present the monthly net social and net family benefits for each military family category for each installation included in this study. We also show results from the pooled observations from all four installations. The negative signs represent net cost.

**TABLE 24**

*AVERAGE MONTHLY NET BENEFIT OF MILITARY RENTAL HOUSING*

<table>
<thead>
<tr>
<th>Net Benefit To</th>
<th>Installation</th>
<th>Junior Enlisted</th>
<th>Senior Enlisted</th>
<th>Company Grade</th>
<th>Field Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Society</td>
<td>Travis</td>
<td>$141 (8.20)</td>
<td>$123 (18.1)</td>
<td>$120 (25.1)</td>
<td>$139 (47.2)</td>
</tr>
<tr>
<td>Family</td>
<td>Travis</td>
<td>155 (16.2)</td>
<td>116 (39.2)</td>
<td>84 (45.1)</td>
<td>64 (75.1)</td>
</tr>
<tr>
<td>Society</td>
<td>Ellsworth</td>
<td>130 (25.0)</td>
<td>132 (27.2)</td>
<td>192 (30.1)</td>
<td>207 (28.2)</td>
</tr>
<tr>
<td>Family</td>
<td>Ellsworth</td>
<td>145 (36.5)</td>
<td>152 (37.2)</td>
<td>176 (40.9)</td>
<td>135 (34.8)</td>
</tr>
<tr>
<td>Society</td>
<td>MacDill</td>
<td>79 (32.2)</td>
<td>-60 (32.3)</td>
<td>38 (29.0)</td>
<td>91 (21.0)</td>
</tr>
<tr>
<td>Family</td>
<td>MacDill</td>
<td>83 (62.1)</td>
<td>-13 (42.1)</td>
<td>26 (25.3)</td>
<td>3 (28.1)</td>
</tr>
<tr>
<td>Society</td>
<td>Tinker</td>
<td>2 (2.10)</td>
<td>-6 (6.10)</td>
<td>47 (35.0)</td>
<td>40 (40.0)</td>
</tr>
<tr>
<td>Family</td>
<td>Tinker</td>
<td>26 (12.2)</td>
<td>38 (13.8)</td>
<td>23 (27.3)</td>
<td>28 (25.0)</td>
</tr>
<tr>
<td>Society</td>
<td>*Four Base Average</td>
<td>71 (16.2)</td>
<td>100 (22.0)</td>
<td>49 (27.8)</td>
<td>119 (38.5)</td>
</tr>
<tr>
<td>Family</td>
<td>*Four Base Average</td>
<td>99 (26.3)</td>
<td>79 (34.5)</td>
<td>75 (40.5)</td>
<td>57 (46.6)</td>
</tr>
</tbody>
</table>

*Weighted average with respect to proportion of population in each category at each installation. Values in parentheses are standard deviations.*
We consider it appropriate to briefly explain why, for some categories and installations, the net social benefit exceeds the net family benefit. After examining the data in light of equation 4 from Chapter IV, we found that for some categories and installations, the DoD is simply taking in more money per family in terms of forfeited monthly BAQ (\(P_J^Q_J\) in equation 4) than it pays out in terms of average monthly costs (\(AC_H^M\) in equation 4).

We close this section with a brief discussion of the sensitivity of our net social and net family benefits to variations in our estimates for the elasticity of demand for housing service, \(PHQ_H^J\) and \(PHQ_J^J\). First, we tested the sensitivity of net social and net family benefits to variations in elasticity (\(\varepsilon\)) over the range \(-0.7 \leq \varepsilon \leq -1.7\). On the average, our estimates of net benefits varied only a few dollars over this range (plus or minus eight-tenths of one percent). Second, we tested the sensitivity of our results to variations over the range of optimism (\(AG1\)) to pessimism (\(AG3\)) for owner-occupied imputed rents. We found that on the average, our estimates of net benefits varied plus or minus eight percent from our realistic (\(AG2\)) mid point. Third, we tested the sensitivity of our results to variations in our estimate of \(PHQ_J^J\). We found that on the average, a plus or minus variation of ten percent in \(PHQ_J^J\) resulted in a plus or minus variation of less than three percent in our estimates of net benefits. Given the results of our sensitivity analysis and

\[5\text{Our estimate of } PHQ_H^H \text{ includes pooled home owner and private renter imputed rents. Since the imputed rents for private renters were directly observable from the data, we did not include variations in these values in our sensitivity analysis.}\]
the assumptions of our model, we feel relatively confident that the net social and net family benefits presented in Table 24 are realistic measures.

This concludes our presentation and explanation of our results from our benefit cost model. In the following section, we present the results obtained from our housing service consumption model.

An Analysis of Alternative Amounts of Housing Service Consumption

In Table 25, we present a comparison of alternative amounts of housing service consumption obtained from the model presented in Chapter V. Essentially our model tested whether the current DoD housing program induced military families to consume more or less housing service than they otherwise would in the private market.

### TABLE 25

<table>
<thead>
<tr>
<th>Installations</th>
<th>Junior Enlisted</th>
<th>Senior Enlisted</th>
<th>Company Grade</th>
<th>Field Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travis</td>
<td>$Q_J &gt; Q_H$</td>
<td>$Q_J &gt; Q_H$</td>
<td>$Q_J = Q_H$</td>
<td>$Q_J &gt; Q_H$</td>
</tr>
<tr>
<td>Ellsworth</td>
<td>$Q_J &gt; Q_H$</td>
<td>$Q_J &gt; Q_H$</td>
<td>$Q_J &lt; Q_H$</td>
<td>$Q_J &lt; Q_H$</td>
</tr>
<tr>
<td>MacDill</td>
<td>$Q_J &lt; Q_H$</td>
<td>$Q_J = Q_H$</td>
<td>$Q_J = Q_H$</td>
<td>$Q_J &lt; Q_H$</td>
</tr>
<tr>
<td>Tinker</td>
<td>$Q_J &lt; Q_H$</td>
<td>$Q_J = Q_H$</td>
<td>$Q_J = Q_H$</td>
<td>$Q_J &lt; Q_H$</td>
</tr>
<tr>
<td>Four-base pooled observations</td>
<td>$Q_J &gt; Q_H$</td>
<td>$Q_J &gt; Q_H$</td>
<td>$Q_J &gt; Q_H$</td>
<td>$Q_J &lt; Q_H$</td>
</tr>
</tbody>
</table>

*The mean values of $Q_J$ and $Q_H$ for each category were tested for significant difference. The differences for all inequalities were significant except for junior enlisted and company grade categories at MacDill and the field grade category at Travis and Tinker. Equal signs indicate no difference in mean values for $Q_J$ and $Q_H$. 


With two exceptions, we find that the current DoD housing program induces junior and senior enlisted families to consume more housing service than they otherwise would in the private market. The two exceptions are junior enlisted families at Tinker and senior enlisted families at MacDill. Also, we note that the DoD housing program had no observed effect on senior enlisted housing consumption at Tinker.

Using pooled observations, our analysis indicates that company grade families would consume more housing service in the private market. However, the current DoD program has mixed results with regard to company grade families at each of our four installations.

Using pooled observations, our analysis indicates that field grade families would consume more housing service in the private market. With regard to each installation, field grade families are induced to consume more housing service at Travis and Ellsworth compared to the private market and they consume less at MacDill and Tinker compared to the private market.

We have now completed our presentation and interpretation of results from all three models presented in this study. We conclude this chapter with the hope that these results prove useful in subsequent policy analysis and with the expectation that further research will improve and refine the models and the results obtained in this study.
VIII. SUMMARY AND CONCLUSIONS

As stated in Chapter I, our purpose in this study was to first explain the effects of the current DoD housing program on military family housing consumption behavior. Second, we evaluated the current DoD program in terms of social benefits and costs, and third, we evaluated the current program in terms of whether it achieves its stated purpose of increasing the amount of housing service consumed by military families.

Consistent with our purpose, we presented a logit model in Chapter III which expressed the probability of choice of home ownership, private rental, or military rental as a function of the respective differences in monthly cost, distance-to-work, and number of bedrooms across housing sectors and income (RMC), number of persons in family, and expected period of dwelling unit occupancy across families. The empirical application of our logit model resulted in the expected coefficient signs, and with the exceptions explained in Chapter VII, all coefficients were significant.

There are a number of possible applications for our logit model. For example, our model provides a means for predicting the probabilities of housing choice given the observed values of the independent variables. These probabilities can be used to assess the impact of large scale personnel transfers on local private housing markets and on available military rental housing. Also, the estimated elasticities can be used to predict changes in the probabilities of choice caused by
government induced changes in the values associated with one or more of the independent variables. Other possible applications include predicting the impact of changes in military rental housing eligibility criteria and assessing the impact of changes in local housing market conditions. However, as we indicated earlier, these applications are left to further research.

We make the following recommendations with regard to the direct application of our logit models. First, the models are generally applicable to any military installation within the continental United States, given that the assumptions of the model are met. In particular, we caution other researchers to insure that the freedom of choice assumption is indeed valid before applying the model. Second, in those cases where the assumptions of the model are not valid, we note that logit model theory as presented in Chapter III provides an excellent framework with regard to problems of housing sector choice and that the theory can be applied to develop other estimated models which fit a particular situation.

Finally, we note that certain refinements to the logit model would improve its explanatory power for policy applications. Specifically, our empirical work was limited by the availability of data for certain variables. We estimated values for the expected period of occupancy of private and military renters and our data for income did not include possible income from other than military sources. We suspect that the accuracy of the coefficients would be improved if these data were directly available. However, we do not anticipate a change in the signs of our estimated coefficients.

In Chapter IV, we presented a benefit-cost model which permitted
an evaluation of the current DoD housing program in terms of social benefits and costs. Essentially, our model provides a method for estimating the mean net social and the mean net family benefit per family for junior enlisted, senior enlisted, company grade, and field grade families.

The empirical application of our benefit-cost model resulted in reasonably accurate estimates of mean net social and net family benefits for each of the four categories and installations included in this study, given the assumptions of the model. However, future research might include testing and/or relaxing the assumptions of the model and refining the estimates of social costs which were used as a basis for our estimate of net social benefit. Also, our estimate of the private market equivalent rent for a military rental dwelling unit \( P_{H0J} \) should be refined. Specifically, we recommend that \( P_{H0J} \) be estimated using Olsen's method as outlined in Chapter IV. Our estimates of \( AC_M \), the average cost per unit of housing service to the DoD, were obtained from Headquarters U.S. Air Force and represent the best data available at the time of this study. We do not preclude the possibility that more precise data can be obtained, however, such extensive research is far beyond the scope of this study. Until the refinements that we have identified are made, we caution against the use of our mean estimates for policy decisions which require precise dollar amounts.

We also recommend that a more extensive statistical analysis of the refined estimates of net social and net family benefits be performed.

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1We note however, that the data on \( AC_M \) do not include the opportunity cost of the land associated with each dwelling unit. In this respect, \( AC_M \) is probably an underestimate.
In particular, variances from the mean for each estimate should be calculated and certain statistical tests should be applied to determine if the estimates are statistically different across categories.

Finally, we note that the value of our benefit cost model lies primarily in the methodology and theory, not in the particular estimates which admittedly need refinement and further statistical tests. In particular, we note that our theoretical model extends the work of Olsen and Bish to the area of military family housing. Further, our estimates of net social benefits, though in need of refinement, clearly indicate that overall, the current DoD housing program results in a net social benefit rather than a net social cost compared to private market alternatives at the installations included in this study.

In Chapter V, we presented a second model for evaluating the current DoD housing program. Essentially, the model provides a means for determining whether the program induces military families to consume more or less housing service than they otherwise would in the private market. The assumptions of our model were essentially the same as the assumptions used for our benefit-cost model, we therefore suggest that future refinements might be made by testing and/or relaxing our assumptions and refining the estimates of net social costs, $P_{HJ}$, and $AC_M$.

As is apparent from our statements throughout this chapter, we believe that this study represents only the beginning of a much-needed comprehensive analysis of the current DoD housing program. Aside from the issues of quantity and quality of housing service available to military families, we note that in fiscal year 1978, DoD family housing and assistance programs involved a total obligation authority of over
1.5 billion dollars. The current DoD housing program is obviously big business; we submit that taxpayers deserve an efficient and effective program consistent with the intent of Congress.²

²Public Law 345, op. cit.
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