CHANGES IN THE STOCHASTIC PLANNING HORIZON

AND ITS EFFECT UPON THE ELDERLY

by

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(1984)

Submitted to the Department of Economics
in Partial Fulfillment of
the Requirements for the Degree of

DOCTOR OF PHILOSOPHY

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December 1989

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December, 1989

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ABSTRACT

When individuals are making decisions regarding the purchase of a durable commodity, the choice of job, or any other decision that has a time duration element to it, these decisions critically depend upon the lifetime or the time horizon of the object being decided upon. The reason that the time horizon is so critical comes from the fact that the worth of each option depends not only upon its initial value, but also its value over time. For an elderly person, the durable or useful life of an object is often greater than the remaining lifetime of the person. In situations where this is true, the relevant planning horizon is the individual's time until death. Since the date of an individual's death is unknown in advance, this creates a stochastic planning horizon.

To see how the stochastic planning horizon of the elderly changed with time, the first chapter of this thesis examines elderly mortality and how it is changing over time. The method used in Chapter I to describe the mortality experience of the elderly is the time to failure or hazard model. Using this approach, a time varying version of Gompertz's Law is developed and estimated. The estimated model is then used both as a way to quantify exactly how mortality for elderly has been changing and as a basis for estimating life expectancies in the subsequent chapters of this thesis.

The elderly's housing decision, a decision where the effective time horizon is the person's remaining lifetime, is the focus of the second chapter. The econometric model of the decision to move or not to move, developed and estimated in this chapter, explicitly incorporates the changing and stochastic nature of the elderly's planning horizon in this type of situation. Another important feature of the model is that unobserved differences (unobserved heterogeneity) between households are accounted for in the decision process.

The third chapter turns again to mortality. This chapter develops a method to use both observed and unobserved characteristics of elderly males to estimate the effect that the various observed characteristics have upon the survival probability of elderly males. These estimates are then used to look at some specific implications of the changing elderly male mortality.

Thesis Supervisor: Daniel McFadden
Title: Professor of Economics

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Above all, I want to thank my wife Lisa and our children for creating such a wonderful environment at home that I could always keep a proper perspective on life. They were my greatest source of strength and support. This thesis is dedicated to them, with all my love and thanks.

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CHAPTER I

Changing Elderly Mortality

An important consideration in any decision making process is the length of the time horizon; how much longer someone must endure something that is unpleasant or how much longer someone is able to enjoy something that appeals to them greatly influences whether or not they will choose it. Because of their age, the relevant time horizon for many of the elderly's decisions is the amount of time until their death. For this reason, it is essential to have a good understanding of the mortality experience of the elderly and how the mortality of the elderly is changing over time.

A common method used to describe the mortality experience of a group of individuals is to examine how much longer the individuals in the group have to live conditioned upon the fact that these individuals are alive today. The type of model best suited for this kind of analysis is the time to failure, or hazard approach (where in this case a failure occurs when an individual dies). The hazard function is defined by:

$$(1) \qquad \mu(x) = \lim_{\Delta x \to 0} \frac{\Pr[x \leq X < x+\Delta x \mid X \geq x]}{\Delta x}$$

The hazard function is just the probability of failure (i.e. dying) at time t, given that the individual had not failed (i.e. was alive) just prior to t.[1]

To get an idea of what the hazard function for mortality looks like at different ages, Figures 1 through 6 plot the log of the mortality hazard rate

[1] In demography and actuarial science, this expression is called the "force of mortality." Although this chapter deals with mortality, the "hazard rate" or just the "hazard" is the term that is used.

by age for white males, white females, non-white males and non-white females using data respectively from the 1969-71 and 1979-81 decennial life tables. Figures 1 and 2 plot the log mortality hazard rate for the four sex-race groups together at a point in time, whereas Figures 3 through 6 plot the log mortality hazard rate at different points of time for each sex-race group separately. From Figures 1 and 2 it is easy to see the "crossover effect"[2] that occurs at elderly ages. Three additional interesting points also emerge from these graphs: first, there are significant differences in the hazard rates for these four sex-race groups; second, the log hazard is nearly linear; and third, there was a noticeable change in the hazard for these groups between 1969-71 and 1979-81. The last three observations about the shape of the hazard function discussed above set the framework for the rest of this chapter.

To examine the differences in the mortality experience for the four different sex-race groups and to quantify exactly how the hazards for these groups changed over time, a parametric model was fit to data from the annual life tables.[3] Utilizing the previously mentioned observation that the log of the mortality hazard is approximately linear, the parametric specification of the model is a Gompertz curve since a Gompertz curve is linear in the log hazard. Gompertz's Law is one of the most frequently used parametric forms

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[2] The "crossover effect" refers to the relative change in mortality between the whites and the non-whites that happens at elderly ages. Before the crossover, a non-white at a given age is more likely to die than a white, whereas after the crossover, a white is more likely to die than a non-white at a given age.

[3] In order to use the data from the annual life tables, a simple transformation of the data was necessary. From the data in the life tables, q_x, the conditional probability of death in the age interval (x,x+1) given that the individual is alive at age x, was formed. The hazard rate then equals $-\ln(1-q_{x-.5})$.

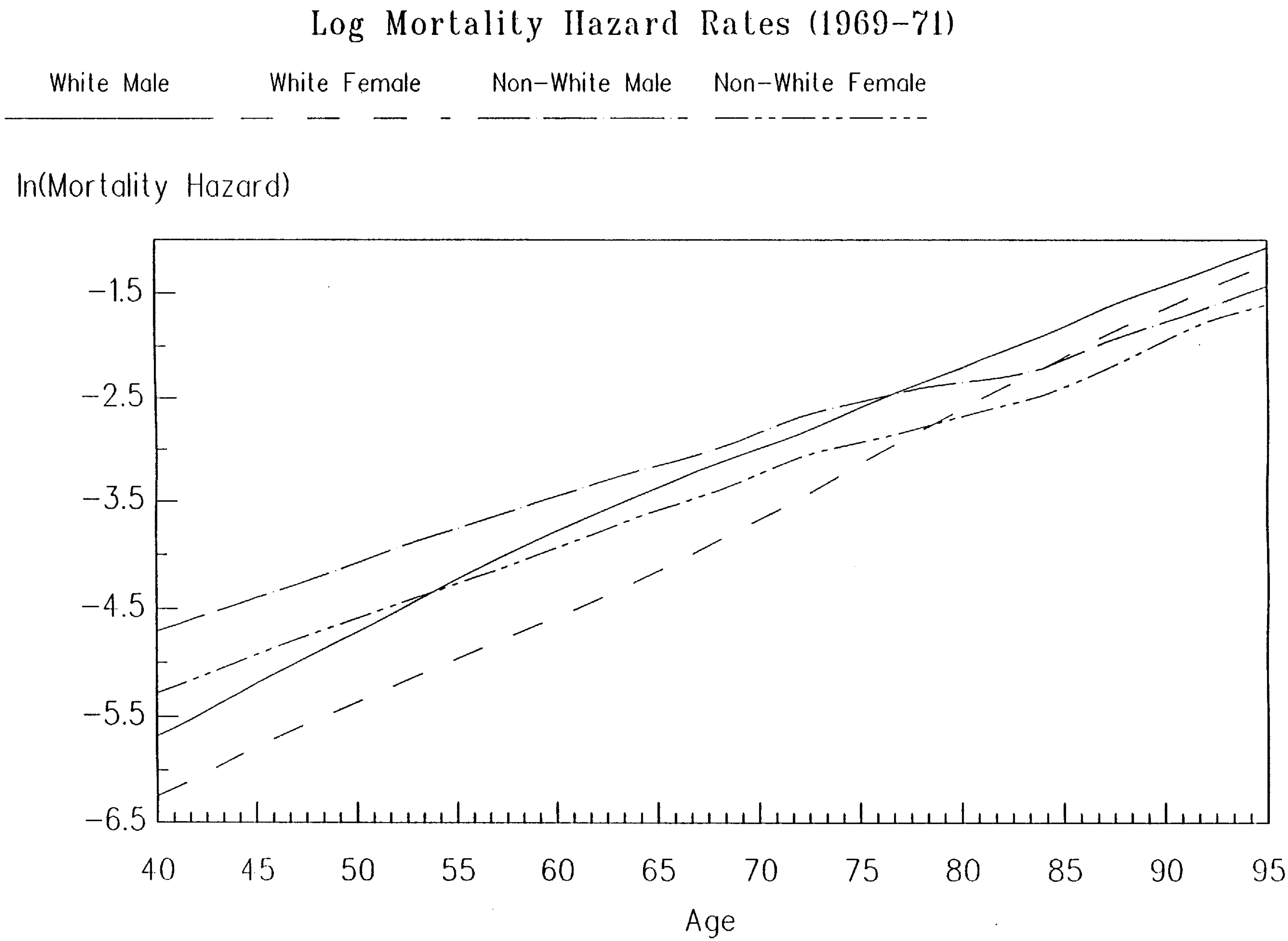
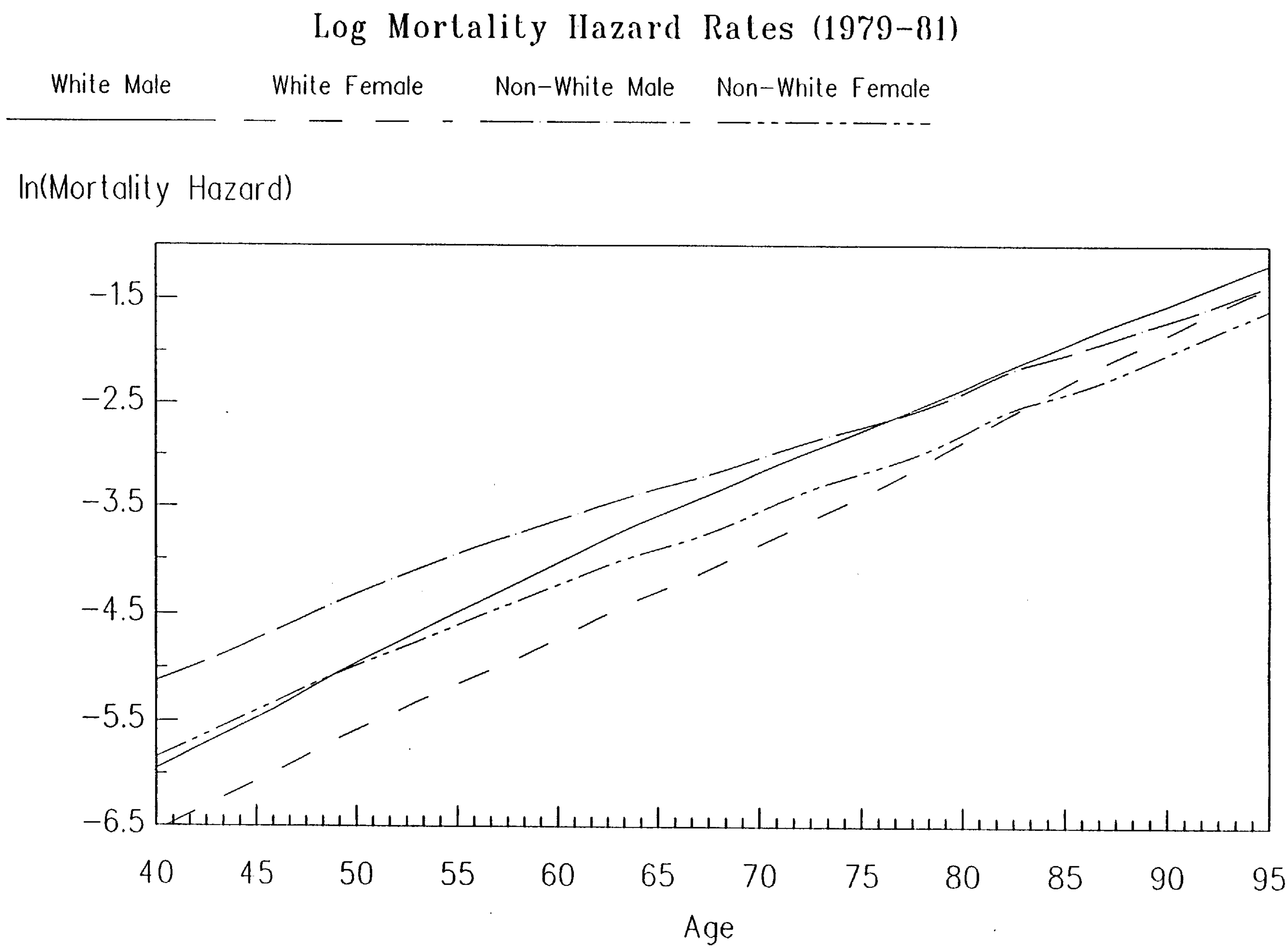

Log Mortality Hazard Rates (1969-71)
White Male
White Female
Non-White Male
Non-White Female
ln(Mortality Hazard)
-1.5
-2.5
-3.5
-4.5
-5.5
-6.5
40
45
50
55
60
65
70
75
80
85
90
95
Age

Figure 1

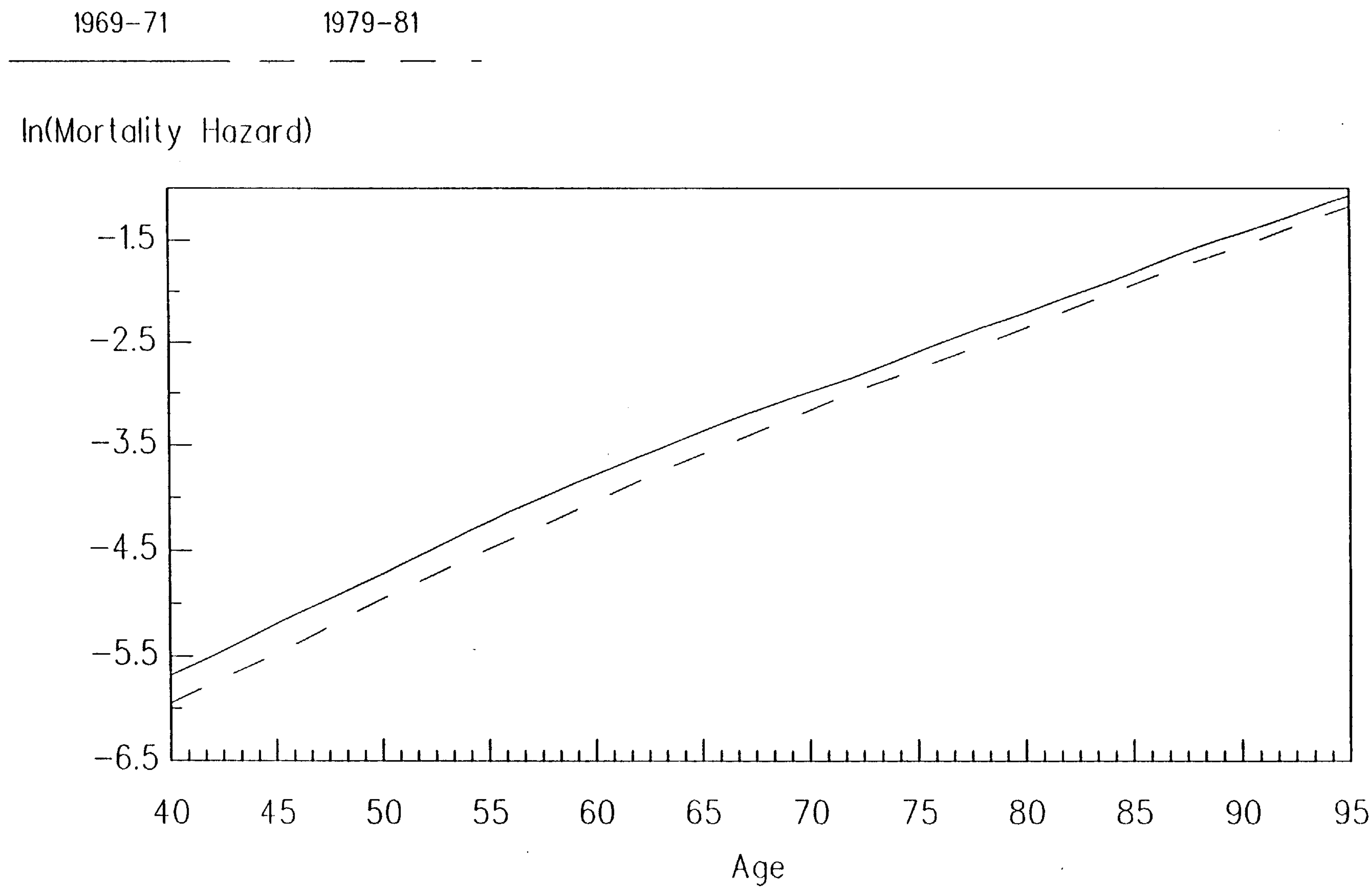
Figure 2



Log Mortality Hazard Rates (1979-81)
White Male
White Female
Non-White Male
Non-White Female
ln(Mortality Hazard)
-1.5
-2.5
-3.5
-4.5
-5.5
-6.5
40
45
50
55
60
65
70
75
80
85
90
95
Age

Figure 3

White Male Mortality Hazard Rates
1969-71 vs. 1979-81



White Female Mortality Hazard Rates
1969-71 vs. 1979-81

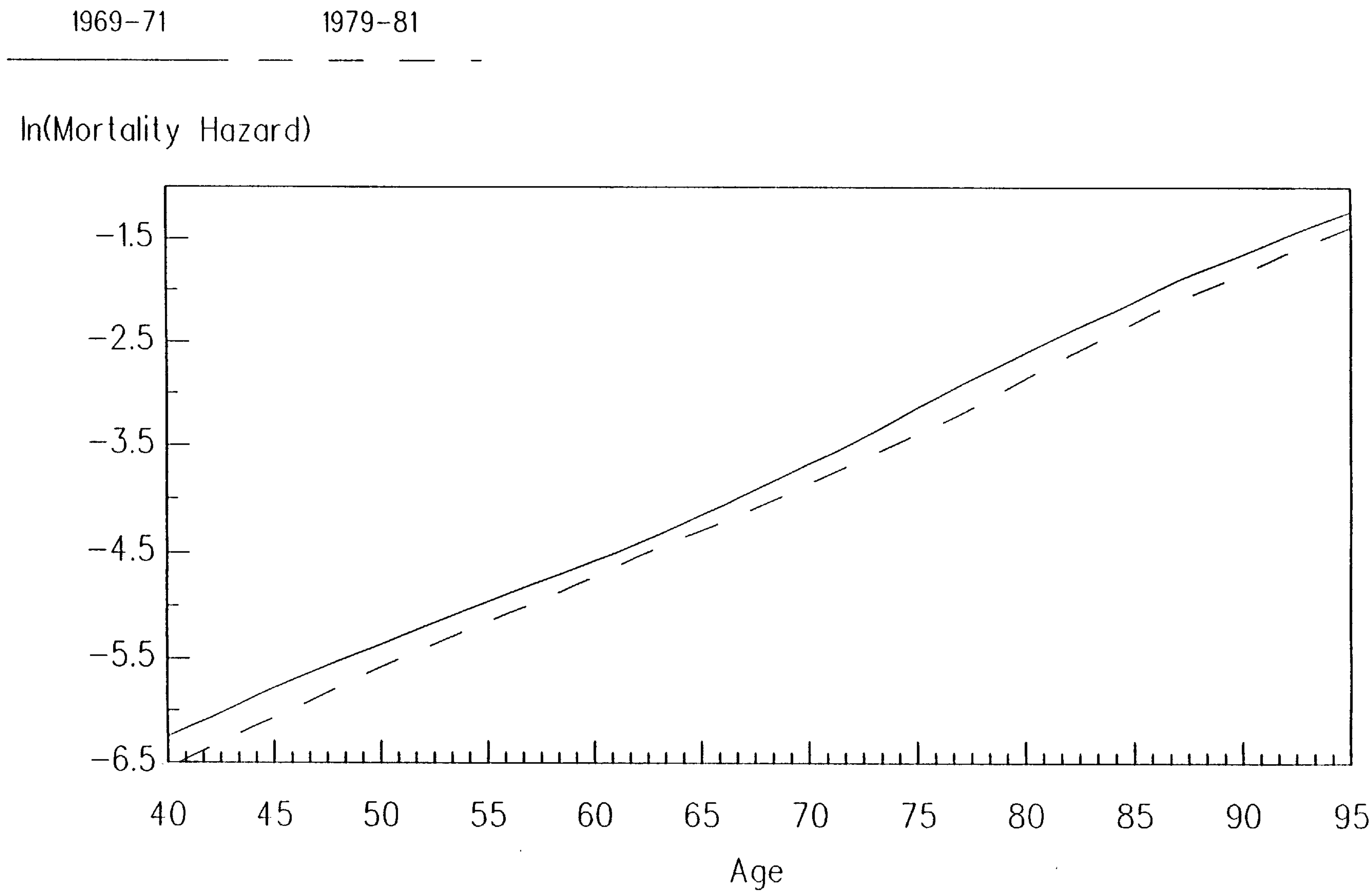


Figure 4

Non-White Male Mortality Hazard Rates
1969-71 vs. 1979-81

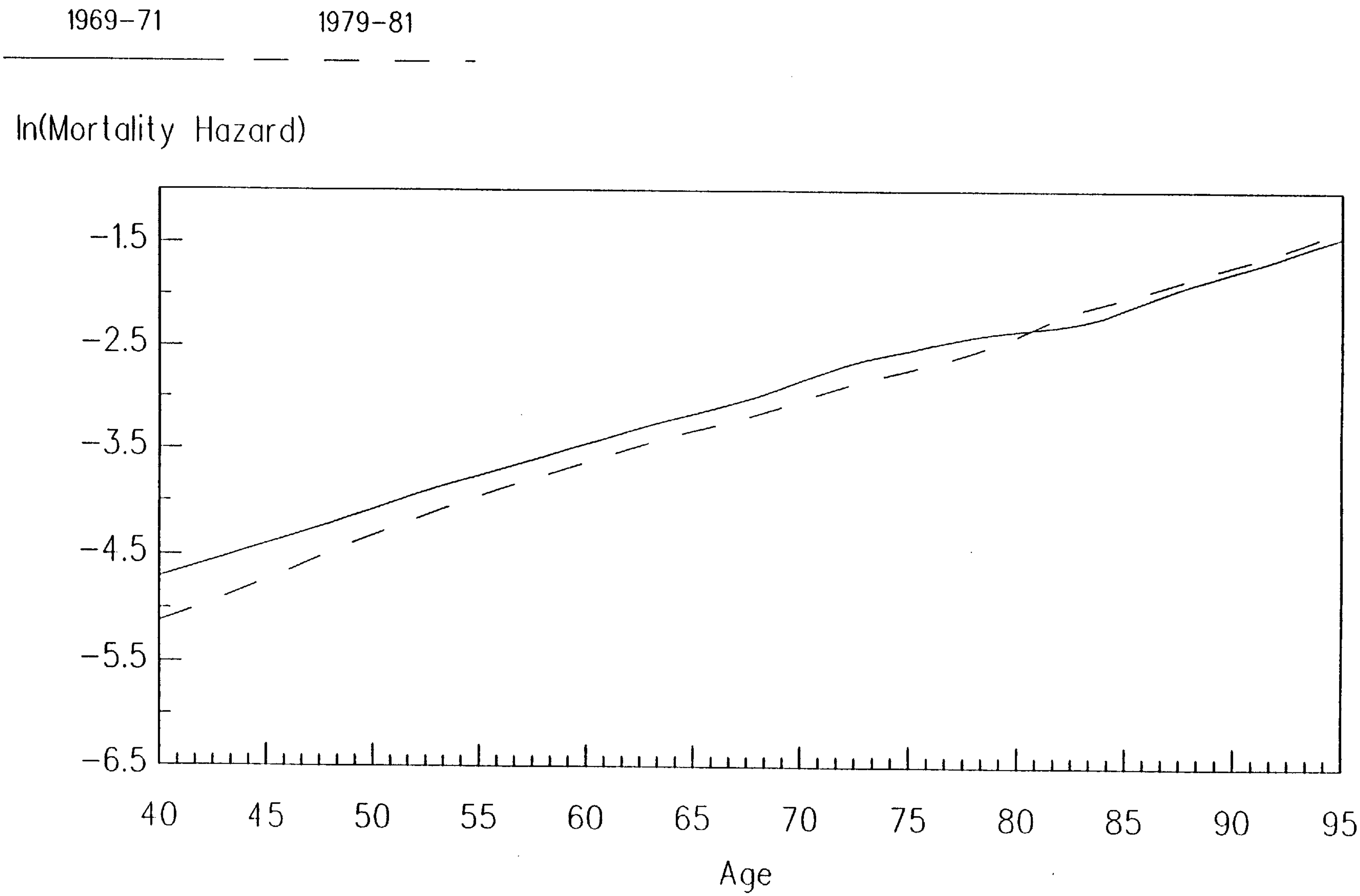


Figure 5

Non-White Female Mortality Hazard Rates
1969-71 vs. 1979-81

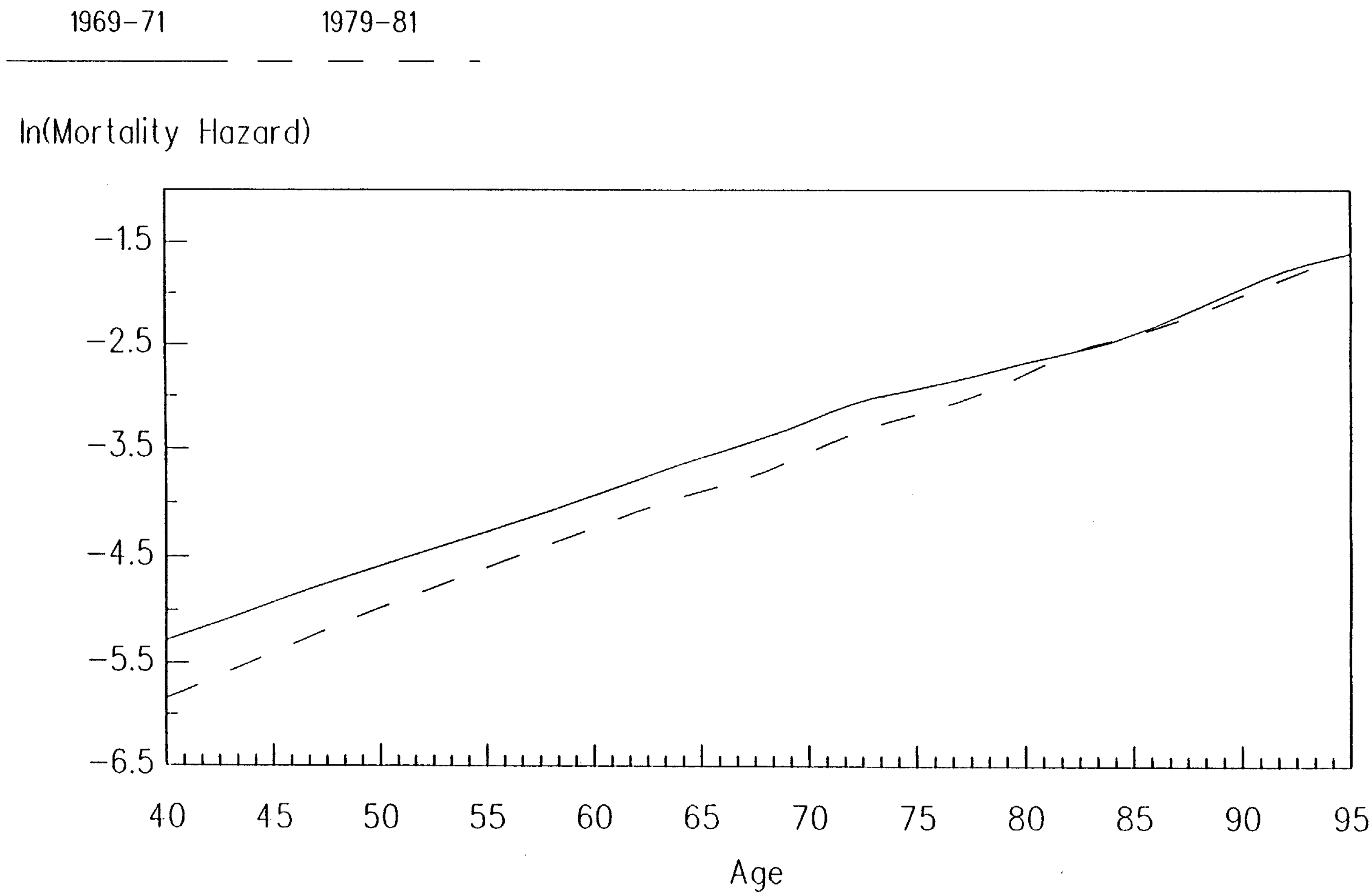


Figure 6

for estimating mortality hazards.[4] The specification of the Gompertz hazard is:

(2) $\mu(x) = \exp(\alpha+\kappa x)$

where x is the age of the individual. The parameter estimates resulting from estimating (2) can be seen in Figures 7 through 10. These graphs plot the estimated values of the parameters α and κ for the four sex-race groups on a year by year basis from 1969 to 1979. From these figures not only is it clear how different the Gompertz parameters are for the different sex-race groups, but it is also easy to see how α and κ are changing over time for each of these four groups. Since α and κ change in roughly a linear manner over time, then in order to capture the changes in mortality over time, α and κ were specified as:

(3) $\alpha = \delta_o + \delta_1 t$

(4) $\kappa = \omega_o + \omega_1 t$

where t is the number of years since 1969 (e.g. calendar year - 1969). The parameter estimates resulting from using (2) with (3) and (4) are found in Table 1. As anticipated, this simple representation of the hazard fits the data quite well. Also notice that by looking at the coefficient that multiplies t, it is possible to see which sex-race group has the greatest changes in mortality over time. The percentage changes in life expectancy for a 65 year old person between 1969 and 1979 follows the same ranking as the

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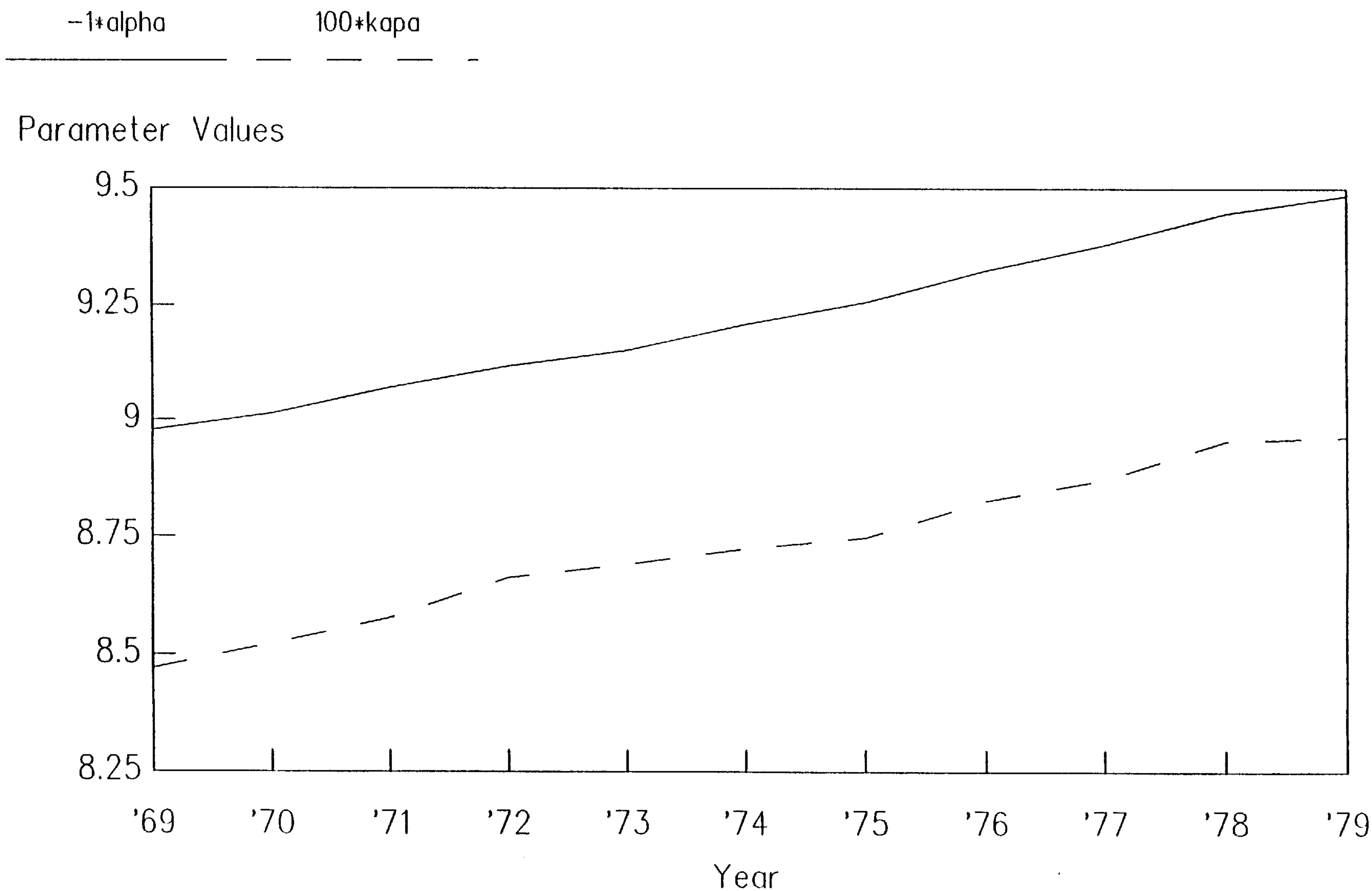
[4] Gompertz's Law is widely used for two reasons: it fits a wide range of mortality data quite well for ages 30-90 and its parameters are easy to estimate. For further discussion see Wetterstrand (1981) and Horiuchi and Coale (1982).

Figure 7

Gompertz Parameters Over Time
(White Males)



Gompertz Parameters Over Time
(White Females)

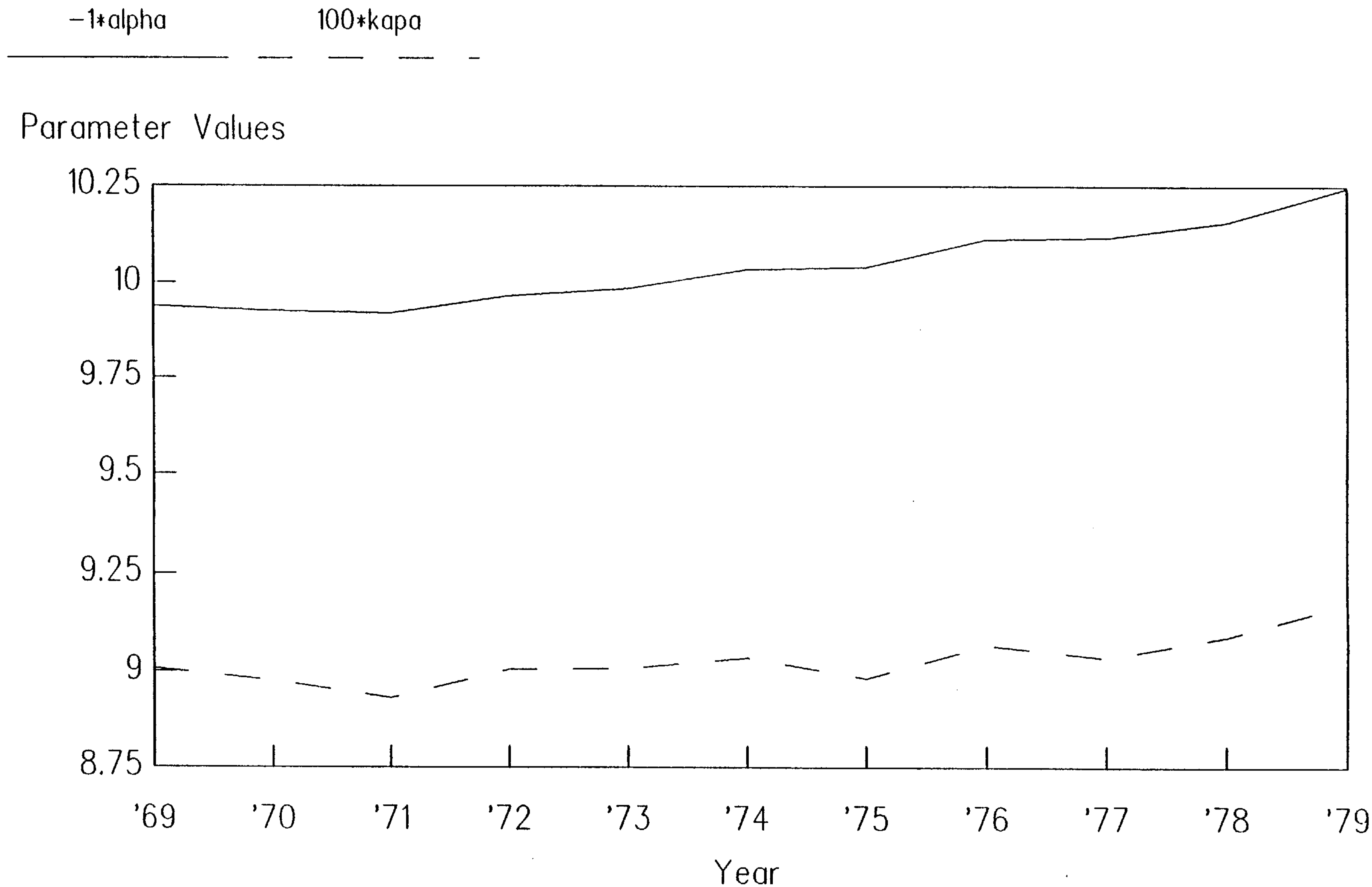
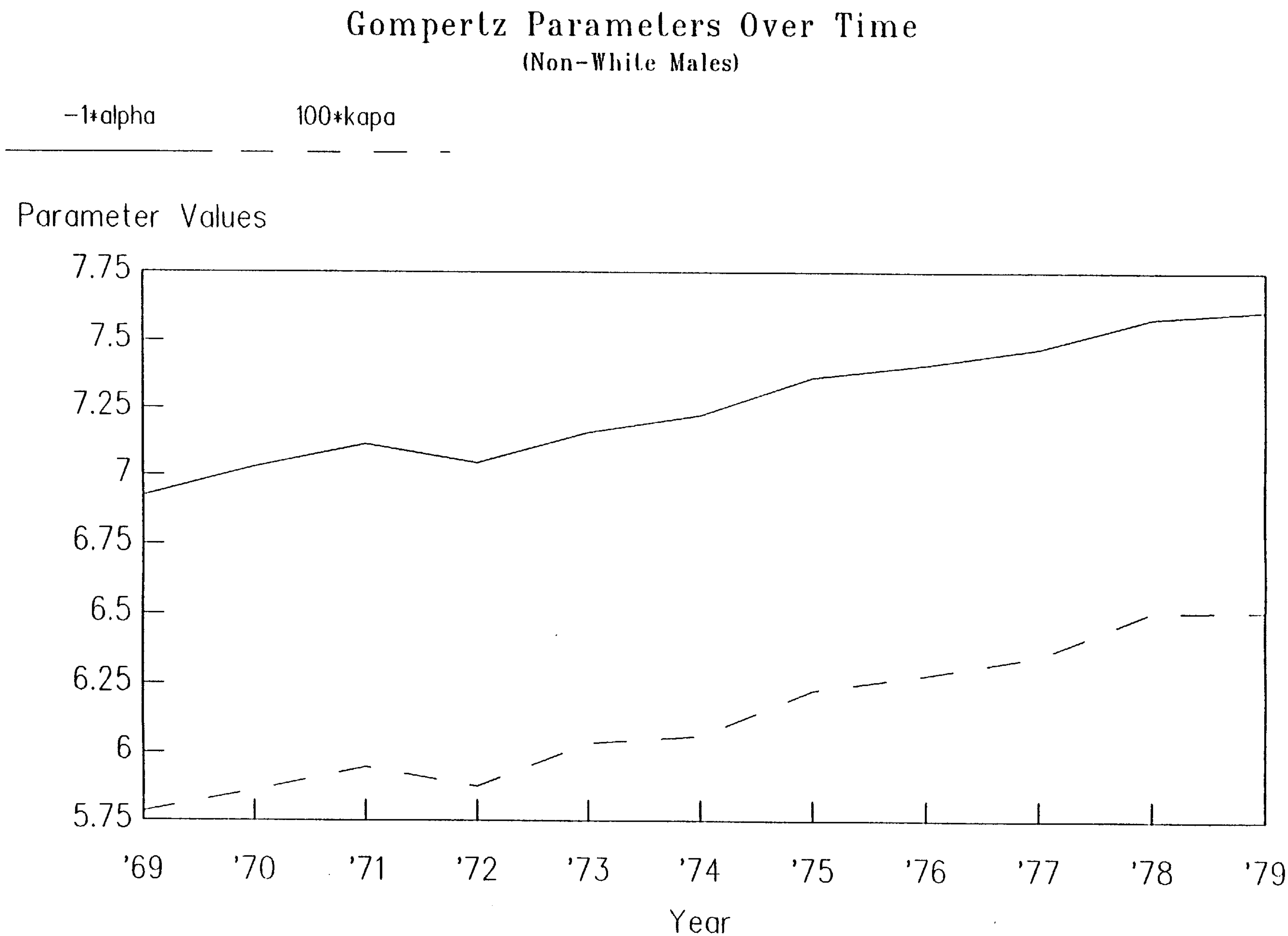


Figure 8

Figure 9


Gompertz Parameters Over Time
(Non-White Males)
-1*alpha
100*kapa
Parameter Values
7.75
7.5
7.25
7
6.75
6.5
6.25
6
5.75
'69
'70
'71
'72
'73
'74
'75
'76
'77
'78
'79
Year

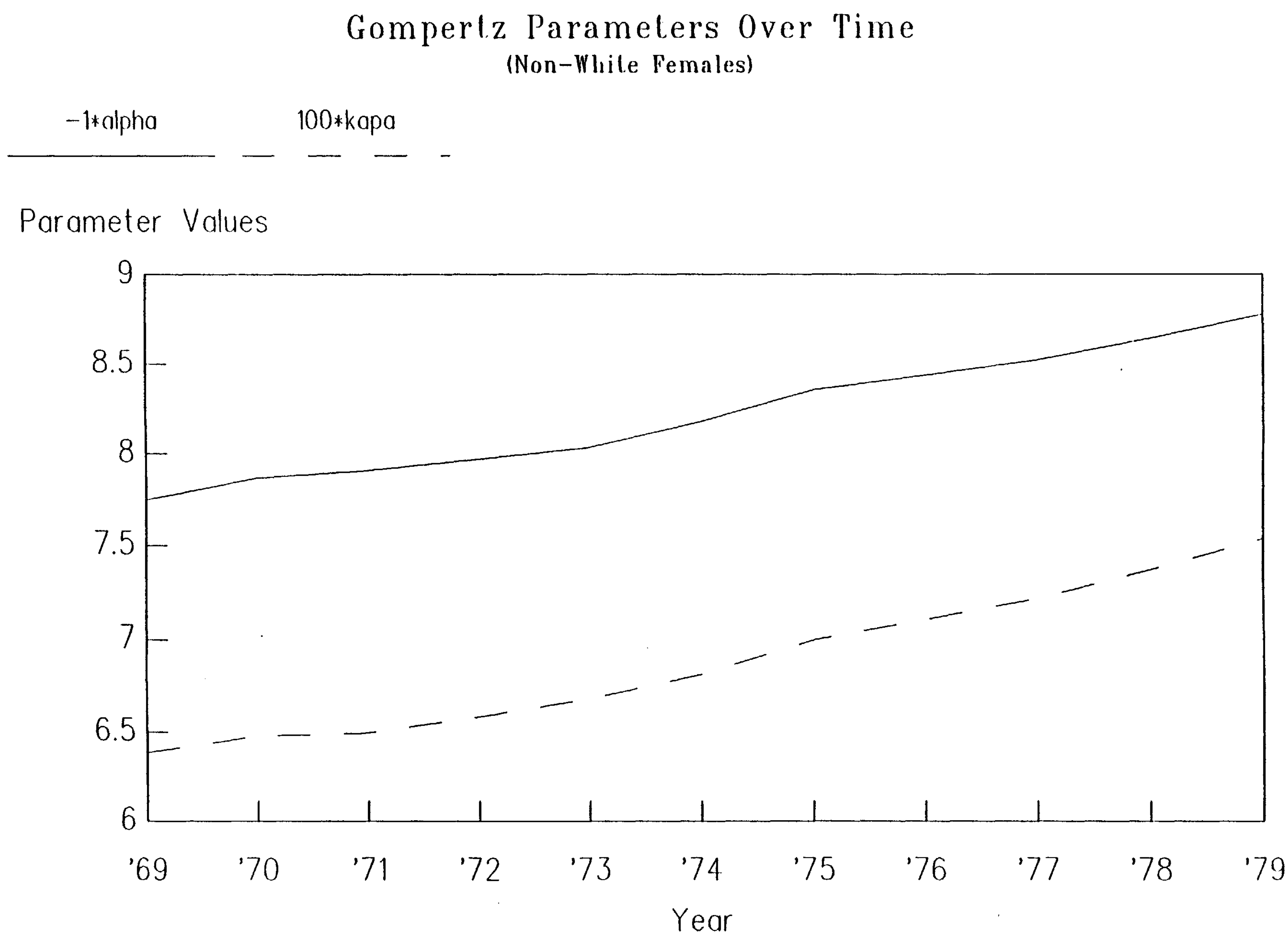

Gompertz Parameters Over Time
(Non-White Females)
-1*alpha
100*kapa
Parameter Values
9
8.5
8
7.5
7
6.5
6
'69
'70
'71
'72
'73
'74
'75
'76
'77
'78
'79
Year

Figure 10

Table 1. Gompertz Parameters

	δ_o	δ_1	ω_o	ω_1
White Males	-8.9088	-0.0522	0.0843	0.0005
	(0.0277)	(0.0041)	(0.0004)	(6.40e-5)
White Females	-9.8540	-0.0311	0.0894	0.0002
	(0.0305)	(0.0045)	(0.0005)	(7.05e-5)
Non-White Males	-6.8500	-0.0695	0.0567	0.0008
	(0.0516)	(0.0076)	(0.0008)	(0.0001)
Non-White Females	-7.6005	-0.1036	0.0618	0.0012
	(0.0620)	(0.0091)	(0.0010)	(0.0001)

Number of Observations (each regression)	495
White Males	
R-squared	0.9974
Sum of Squared Residuals	1.6783
Standard Error of the Regression	0.0585
White Females	
R-squared	0.9970
Sum of Squared Residuals	2.0403
Standard Error of the Regression	0.0645
Non-White Males	
R-squared	0.9819
Sum of Squared Residuals	5.8310
Standard Error of the Regression	0.1090
Non-White Females	
R-squared	0.9795
Sum of Squared Residuals	8.4004
Standard Error of the Regression	0.1308

Standard errors in parenthesis

coefficients δ_1 and ω_1: white females changed by 9.1 percent; white males changed by 8.4 percent; non-white males changed by 7.6 percent; non-white females changed by 7.5 percent.

Using the parameter estimates found in Table 1, two different measures of distributional change can be constructed to examine the changes that occurred in the population mortality during the 10 year period between 1969 and 1979. The first measure is formed by taking the difference between the survival function for 1969 and the survival function for 1979. The Gompertz survival function is defined as:

$$(5) \qquad S_t(x) = \Pr[X > x] = \exp\left[\frac{\exp(\delta_o+\delta_1 t)}{\omega_o+\omega_1 t}\left(1 - \exp((\omega_o+\omega_1 t)x)\right)\right]$$

where x is the age of the individual and t is the number of years since 1969 (e.g. calendar year - 1969). The differences between these two survival functions for ages 0-100 are plotted in Figure 11. From this figure it is clear that (i) the changes in the non-white survival functions were larger than the changes in the white survival functions; and (ii) the changes for the whites were concentrated at older ages than were the changes for the non-whites.

The second measure of distributional change uses the change in expected remaining lifetime (or simply the change in life expectancy). Under Gompertz Law, life expectancy is defined by:

$$(6) \qquad e_x = E_x[X \mid X > x] = \int_0^\infty s\exp\left[\alpha_t+\kappa_t(x+s)+\frac{e^{\alpha_t+\kappa_t x}}{\kappa_t}\left(1 - e^{\kappa_t s}\right)\right]ds$$

where x is the current age of the individual, t is the number of years since

Difference Between the 1979 and 1969
Survival Functions

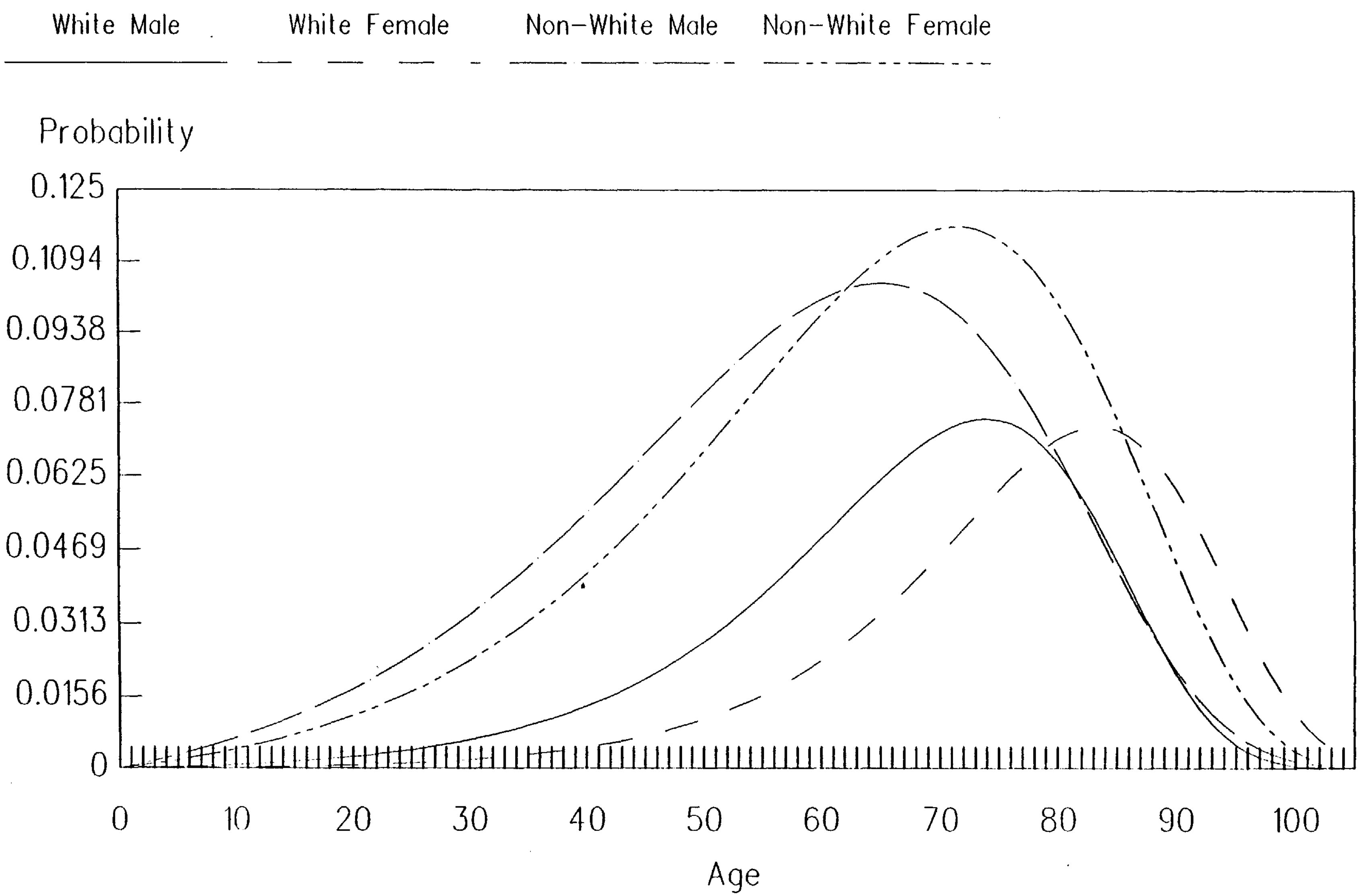


Figure 11

1969, and s is the variable of integration. The differences between the 1969 life expectancies and 1979 life expectancies for ages 30 through 95 are found in Figure 12. This figure illustrates the same two points mentioned in the previous paragraph although somewhat differently. For example, consider the extreme ages of the graph (ages 30 and 95). While the gain in the non-white life expectancy is larger than the whites at the younger ages, the gain in life expectancy for the non-whites is less than the whites at the very old ages. It is also interesting to note from this figure that not only is the gain in life expectancy less for the non-whites at the extremely elderly ages, but at these ages the non-whites are less likely to be alive than they previously were.[5]

The results presented in this chapter, which will be used in the two chapter that follow, show not only that mortality of the population as a whole is declining with time (and by how much it is declining), but also how distinctly different the mortality experience is for the different sex-race groups.

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[5] This last fact is not only evident from the graph, but is also shown in the U.S. Decennial Life Tables. The published life expectancy for a 80 year old non-white male declined from 6.04 years in the 1969-71 tables to 5.69 in the 1979-81 tables. The change in life expectancy during this same period for non-white females was smaller and occurred at a later age (at age 80 the 1979-81 life expectancy was still greater than the 1969-71 life expectancy). The published life expectancy for a 95 year old non-white female declined from 4.58 in the 1969-71 tables to 4.30 in the 1979-81 tables.

Change in Expected Remaining Lifetime
(1979-1969)

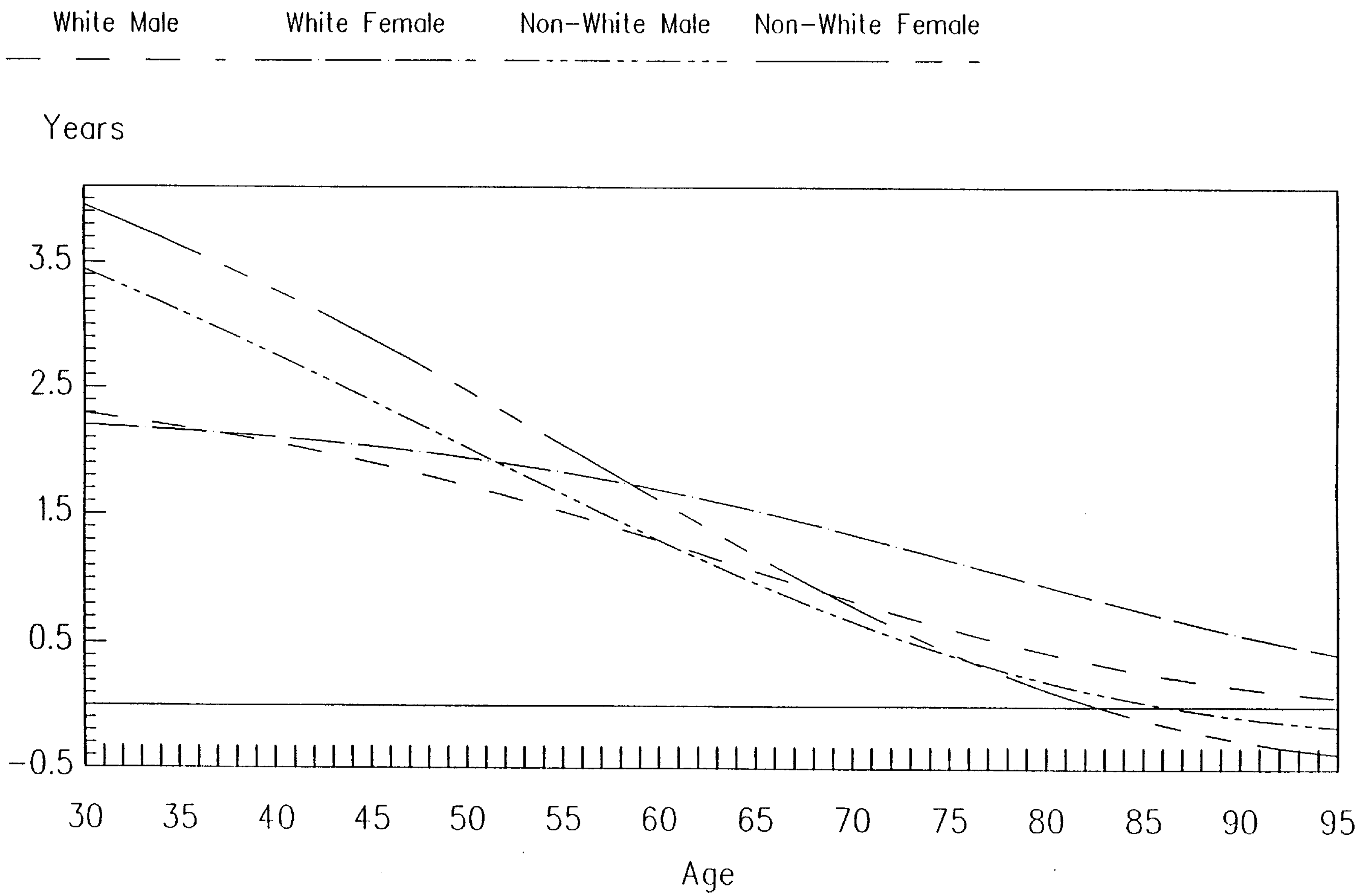

Figure 12

CHAPTER II

Moving and the Elderly: A Stochastic, Finite Horizon Model

As the population of the United States ages and the elderly become a larger proportion of the population, issues associated with the elderly become increasingly important. One of the areas of concern to the elderly where the time horizon is important is housing. The housing needs of an elderly household may not be met for several reasons; in particular, liquidity constraints may force an elderly household to move to lower cost housing; or, a household may be prevented from moving because of the high transactions cost of moving. Since the elderly own a large share of the housing stock[1], and impediments to moving will decrease the elderly's already low mobility rates, there is a potentially large social inefficiency in the allocation of units in the housing market.[2] An understanding of how the elderly are making their housing decisions and what factors trigger a move are necessary in examining these issues.

Perhaps the most striking feature of the housing decisions made by the elderly is their vast diversity.[3] It seems that for every imaginable justification for moving or not moving, every family has its own anecdotal

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[1] While the share of elderly Americans was only 11.5 percent of the population in 1980, those households with a head of age 65 or above accounted for almost a quarter of the owner-occupied housing units in 1981.

[2] For example, think of the scenario of an elderly widow in a large home, who would like to move to a smaller dwelling, but does not because the transactions cost are too large. Also in this scenario is a young family who needs a larger home, but is unable to find one available at the current prices. Here there is clearly the potential for a Pareto improvement.

[3] The stories of the moving behavior of the elderly range from those who lived their entire lives from birth until death in the same house, to those who are living out of a motor home and are constantly "on the move."

evidence of a grandmother, parent, or friend who exhibits such behavior. Amidst the vast diversity of housing decisions, is there anything that is common among households in their decision making? Can anything be said about why people move less as they age, or why some people move more frequently than others?

Recently a number of papers have focused on the housing decisions of the elderly, particularly on the factors that trigger a move. The first group (Merrill (1984), Feinstein and McFadden (1989a), and Venti and Wise (1989a)) contain descriptive statistics and static models. The two major findings of these studies are that when the elderly move, they are as likely to increase as to decrease housing equity, and, that mobility is strongly affected by demographic shocks and retirement. More recently, Feinstein and McFadden, and Venti and Wise have extended their previous work to a more dynamic framework. Venti and Wise (1989b), using the Longitudinal Retirement History Survey (LRHS) and a model analogous to Venti and Wise (1984), followed homeowners until they either purchased a new home and moved or until the survey terminated, whichever came first. Venti and Wise conclude that the low mobility rates among the elderly result from transactions costs that are large relative to the gains available by reallocating wealth from housing to current consumption. Feinstein and McFadden (1989b) have developed and plan to estimate a path utility model of housing choice. Their model will help in understanding how the elderly are making their decisions.

The work in this chapter complements and adds to this literature by using a dynamic framework which allows for heterogeneity among households and explicitly accounts for the time horizon faced by an elderly household. Not only does this type of analytic structure permit the examination of the decision process over time, but it also allows for variables that are changing continuously; in particular, the probability of survival. This last feature is especially important for the elderly, because their acute awareness that lifetimes are finite plays a significant role in their housing decisions. Thus, the decision framework that a household uses in making each of its housing decisions is a cost/benefit analysis which explicitly accounts for the expected mortality of the household.

Estimates for the parameters of the model are obtained by using data from the Longitudinal Retirement History Survey (LRHS). The LRHS initially interviewed households in 1969 whose head was between 58 and 63 years old. These households were reinterviewed every two years, with the last interview being in 1979.

The model used here to describe the housing decisions of the elderly makes it possible to address various aspects of the elderly's housing decisions that formerly could not be addressed. First of all, the incorporation of mortality makes it possible to differentiate between the immediate and the future effects that various factors have upon moving.[4] In looking at the tenure status of a household, estimates from the model indicate that owners have more of an immediate gain (net of cost) when they move, while the gain to renters is more cumulative over time. The combined immediate and long term gains (net of cost) are on average greater for the renters, thus yielding the result that renters move more frequently than owners.

Second, the model allows a household to be followed over many moves and changes in tenure status. One "stylized fact" to emerge from the data is that

[4] Skinner (1985) used mortality in a cross-section model to estimate the intertemporal elasticity of substitution between current and future consumption.

over one-third of those households that moved during the ten year duration of the LRHS moved more than once. Using the estimates from the model, it is not possible to conclude that there is anything intrinsically different about multiple movers except in the most extreme case (i.e. those who move at least once in each two year observation period). This is because the characteristics of the multiple movers are on average more conducive to moving. However, the extreme group is distinct in that there is something that is intrinsically different about these households that makes it advantageous for them to move each period.

Finally, the model can be used to identify which household factors affect a household's probability of moving, and by how much. Here, as was found from the static models, demographic shocks and retirement significantly affect the probability of moving. Furthermore, the model reveals that the time horizon of the spouse also significantly affects the probability of moving. This result suggests that not only are timing considerations important in a household's housing decision, but also that the housing decision is a joint household effort. The ratio of housing costs to a household's fixed income[5] also plays an important role in determining whether or not a household moves. Although earlier papers (Merrill (1984), Feinstein and McFadden (1989a), and Venti and Wise (1989a)) concluded that households are not liquidity constrained because they don't consume their equity, the results found here indicate that there are a significant number of households who need to move in order to adjust downward their ratio of housing costs to fixed income. The difference between these two results arises because the earlier work focused

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[5] This ratio is both a measure of the magnitude of housing costs in a household's monthly expenses and an indicator of a potentially liquidity constrained household.

on changes in equity, an asset, whereas the evidence presented here is based on monthly costs and fixed income. The result found from the analysis in this chapter should be a more accurate measure of the ability of the elderly to remain in their housing because the renters, who have no housing equity and therefore had no effect on the previous results, are those who move most often.

The analysis of this chapter begins by using transition matrices to examine how the housing decisions of the elderly are changing over time without imposing any parametric restrictions on the decision process. The results from this section not only provide a benchmark against which the results from a structural model can be compared, but they also show that considerable heterogeneity exists among elderly households in their housing decisions; heterogeneity that must be incorporated in any structural representation of the elderly's housing decisions. Sections 2 through 4 develop and estimate a structural model of the move/stay decision of an elderly household as a function of its health, economic and demographic characteristics. Section 5 discusses the results of the estimation and shows that the estimated parameters are consistent with the intuition of the model. This section also contains the results from a simulation that examines the effect of a change in Social Security benefits on the move/stay housing decision of the elderly. The concluding section summarizes what was learned by using the model presented here.

1. Dynamic Transitions

Several factors change significantly late in life: job status (e.g.

retirement), family structure, health (life expectancy), etc. An individual has a varying amount of control over these things, ranging from very little to complete control. One factor over which an individual has considerable control is the housing decision. Whether to stay or to move, or to own or to rent, are decisions that are influenced by many different things, but these decisions are ultimately made by the household. Since realizations of the many different events that occur when a person is elderly may change suddenly, it is important to look at both how the elderly's housing decisions respond to changes in particular health, economic or demographic factors, and how the decisions change over time.

To help in the analysis of how the housing decisions of the elderly are changing over time, it is worthwhile to first examine some of these decisions at a specific point in time. The transition probabilities listed below reflect the housing decisions of those in the LRHS between 1973 and 1975.

<u>Transition Probabilities</u>

	Stay			Move		
	Owner	Renter	Other	Owner	Renter	Other
Owner	90.2	0.5	0.8	6.5	1.5	0.5
Renter	2.0	68.9	3.7	3.8	18.4	3.2
Other	2.4	2.7	76.9	1.4	3.4	13.2

From these transition probabilities, it is easy to see how the housing decisions vary by tenure status.[6] This variation is clearly seen by noticing that while 90 percent of those who were owners in 1973 were in the same

[6] The possibility of changing tenure status without moving occurs through a change in financing (e.g. a condo conversion). See the data descriptions in section 4.2 for a description of the tenure variables.

situation in 1975, only 69 percent of those who were renters in 1973 had not moved and were still renting in 1975. The transition probabilities for the other years covered by the LRHS look very similar to those for the 1973-1975 period.

Now that the elderly's housing decisions at a specific point in time have been examined, the tool for analyzing how these decisions vary with time is a four state Markov chain in which the transition probabilities may vary over time. Markov chains are particularly applicable to a panel dataset such as the LRHS, because the amount of time between each survey is constant. The four states are:[7] 1) Stay; 2) Move-same housing tenure, where the tenure types are owners, renters and others; 3) Move-different housing tenure; 4)Die.[8] It is reasonable to assume that death is the only absorbing state in the model, and that eventually all respondents will end up in the absorbing state (i.e. all will die in finite time). A key feature of this approach, which differs from any previous work in this area, is that it includes death as a possible state. Incorporating death is quite important since over 25% of the original respondents in the LRHS died by the last interview of the survey, and failing to including death as a possible state would make the transition probabilities incorrect. The transition matrices and the cell sizes used to compute the transition probabilities are shown in Table 1.

Since the object of interest in using states that are themselves transitions is to see how the housing decisions of the elderly are changing with

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[7] Since the interest here is how the housing decisions are changing with time, then all of the non-absorbing states are defined by the housing decision of a household, which is itself a transition. Thus, these Markov matrices are actually looking at transitions of transitions.

[8] A household is considered to have died when the original respondent associated with the household dies.

TABLE 1. TRANSITION MATRICIES: 1971-1979 ALL RESPONDENTS REGARDLESS OF TENURE STATUS[1]

1971-1973 Transitions

1969-1971 Transitions	1	2	3	4
1	6785 83.86	653 8.07	244 3.02	409 5.05
2	485 61.86	188 23.98	57 7.27	54 6.89
3	227 54.83	87 21.01	74 17.87	26 6.28
4	0 0.00	0 0.00	0 0.00	493 100.00

1973-1975 Transitions

1971-1973 Transitions	1	2	3	4
1	6035 84.08	551 7.68	174 2.42	418 5.82
2	604 66.52	205 22.58	47 5.18	52 5.73
3	234 65.73	43 12.08	54 15.17	25 7.02
4	0 0.00	0 0.00	0 0.00	1026 100.00

1975-1977 Transitions

1973-1975 Transitions	1	2	3	4
1	5486 84.01	445 6.81	167 2.56	432 6.62
2	553 72.19	142 18.54	29 3.79	42 5.48
3	148 58.04	47 18.43	39 15.29	21 8.24
4	0 0.00	0 0.00	0 0.00	1615 100.00

1977-1979 Transitions

1975-1977 Transitions	1	2	3	4
1	4959 83.63	369 6.22	150 2.53	452 7.62
2	448 73.08	101 16.48	22 3.59	42 6.85
3	157 71.69	19 8.68	26 11.87	17 7.76
4	0 0.00	0 0.00	0 0.00	2216 100.00

1 - Stay
2 - Move to the same tenure
3 - Move to a different tenure
4 - Die

[1] Death refers to the death of the head of the household (i.e. once the respondent dies, the household is no longer followed).

time, then the best way to understand the information found in Table 1 is to pick a particular cell in a matrix and compare the same cell in the matrices for the different time intervals. For example, the (2,1) cell in the first matrix corresponds to those households who moved between 1969 and 1971 to the same housing tenure and then did not move between 1971 and 1973. Looking at the (2,1) cell of the other matrices in Table 1, we observe that over time, a household that moves in one period becomes less likely to move again by the following survey.

It is interesting to note that for all of the matrices in Table 1, the conditional probability of moving given a recent move is greater than the conditional probability of moving given no recent move. These conditional probabilities are plotted in Figure 1, where it is easy to see that the decisions of the movers are converging over time to those of the stayers. It is also clear from this figure that households become less mobile over time.[9] It may seem surprising that someone who just moved would be more likely to move again, given that they had just recently made an adjustment in their housing, but it is less surprising if the costs associated with moving are considered. The attachment effect (see Venti and Wise(1984)) will be minimal because the household had insufficient time to attach itself to the new community. Accumulation will also be smaller, since a household will have had little time to collect and gather many additional belongings. The difference in these conditional probabilities also agrees with the fact that in the LRHS, over one-third of the households that moved, moved more than

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[9] There are many different forces acting upon the moving decision that change over time, with age being one of these changing forces. A graph similar to Figure 1, but controlling for the effect of age, looks quite similar to Figure 1. This suggests that the change in behavior implied by Figure 1 is not due solely to the population aging.

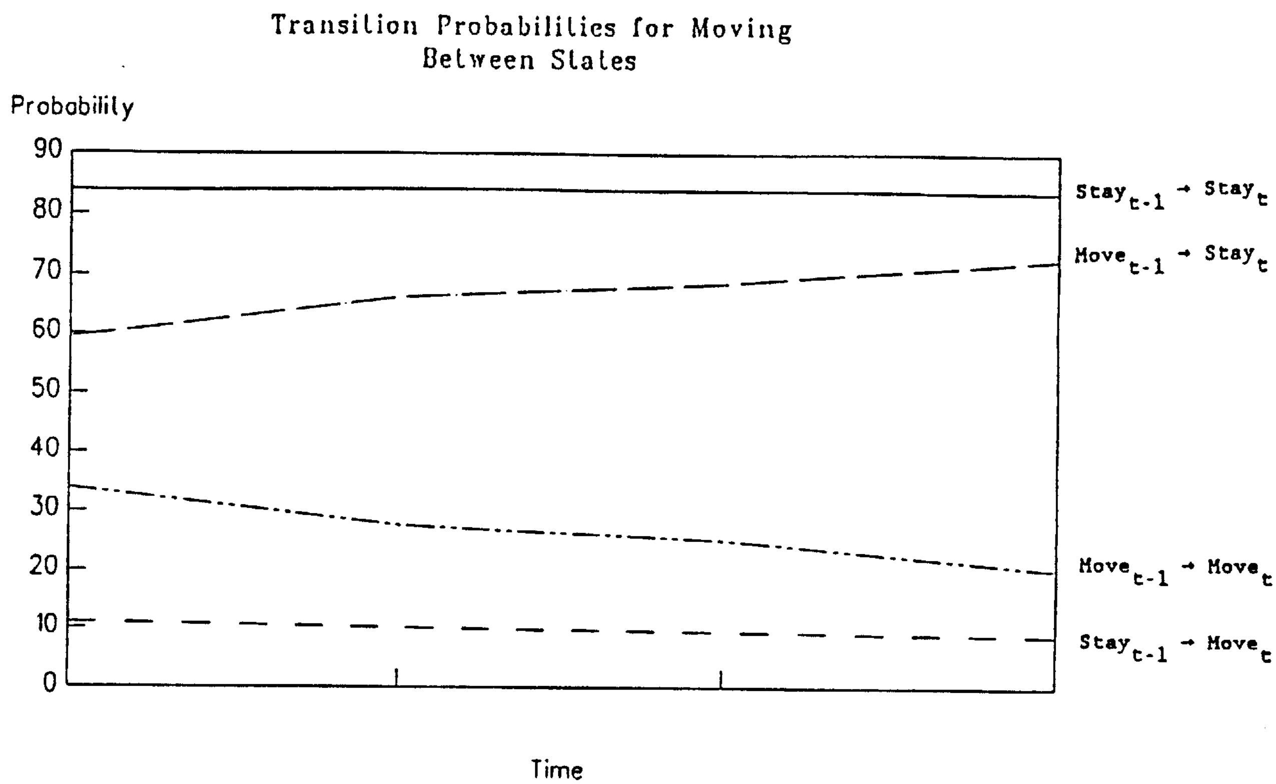
Transition Probabilities for Moving
Between States
Probability
90
80
70
60
50
40
30
20
10
0
$Stay_{t-1} \to Stay_t$
$Move_{t-1} \to Stay_t$
$Move_{t-1} \to Move_t$
$Stay_{t-1} \to Move_t$
Time

Figure 1

once. This, coupled with the observation that those who move to a different tenure type usually have a higher mortality rate than both those who don't move and those who move to the same tenure type, suggests that there is significant heterogeneity in the data.

To obtain a more complete description of the transition probabilities, and to control somewhat for the heterogeneity in the data, the definition of the possible states may be expanded to add the three different tenure types for each state (i.e. there are now 12 states). The resulting matrices are found in Tables 2-5. The blocks on the main diagonals in Tables 2-5 correspond to the same tenure type (i.e. the upper left hand block corresponds to those who were owners at the beginning of both of the periods in the table during which a housing decision was made). For example, the (2,1) element of the matrix in Table 3 contains those households who owned their residence in 1971, moved to owning another residence between 1971 and 1973, and then did not move between 1973 and 1975. As was the case with the single period transition probabilities given earlier, these tables show that there is a significant amount of variation in the transition probabilities for the different tenure types. Given the large number of owners relative to the other tenure types, the aggregate statistics listed in Table 1 are heavily weighted to coincide with the transition probabilities of the owners. This can be seen clearly in one of the aforementioned results, namely the difference in mortality between those who recently moved to a different tenure type and those who were in one of the two other reoccurring states. Looking at Table 3 for example, this inequality in the probability of dying holds only for the owners and not for the renters or the others. Tables 2-5 also show a large difference between owners and renters in how mobility changes over time.

TABLE 2. TRANSITION PROBABILITIES BY TENURE STATUS 1971-1973

1971-1973 Transitions

1969-1971 Transitions	Owners 1	Owners 2	Owners 3	Owners 4	Renters 1	Renters 2	Renters 3	Renters 4	Others 1	Others 2	Others 3	Others 4
Owners 1	4176	291	90	238	22	1	1	0	33	3	4	6
	85.84	5.98	1.85	4.89	0.45	0.02	0.02	0.00	0.68	0.06	0.08	0.12
Owners 2	190	40	10	16	0	0	0	0	0	0	0	0
	74.22	15.63	3.91	6.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Owners 3	0	0	0	0	45	31	23	6	13	2	11	1
	0.00	0.00	0.00	0.00	34.09	23.48	17.42	4.55	9.85	1.52	8.33	0.76
Owners 4	0	0	0	246	0	0	0	0	0	0	0	0
	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Renters 1	33	4	3	2	955	195	110	88	39	2	5	2
	2.29	0.28	0.21	0.14	66.41	13.56	7.65	6.12	2.71	0.14	0.35	0.14
Renters 2	0	0	0	0	217	104	41	30	0	0	0	0
	0.00	0.00	0.00	0.00	55.36	26.53	10.46	7.65	0.00	0.00	0.00	0.00
Renters 3	82	20	3	7	0	0	0	0	41	14	22	7
	41.84	10.20	1.53	3.57	0.00	0.00	0.00	0.00	20.92	7.14	11.22	3.57
Renters 4	0	0	0	0	0	0	0	147	0	0	0	0
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00
Others 1	54	2	3	3	49	5	7	3	1416	150	21	67
	3.03	0.11	0.17	0.17	2.75	0.28	0.39	0.17	79.55	8.43	1.18	3.76
Others 2	0	0	0	0	0	0	0	0	78	44	6	8
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	57.35	32.35	4.41	5.88
Others 3	18	1	4	2	28	19	11	3	0	0	0	0
	20.93	1.16	4.65	2.33	32.56	22.09	12.79	3.49	0.00	0.00	0.00	0.00
Others 4	0	0	0	0	0	0	0	0	0	0	0	79
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00

1 - Stay
2 - Move to the same tenure
3 - Move to a different tenure
4 - Die

TABLE 3. TRANSITION PROBABILITIES BY TENURE STATUS 1973-1975

1973-1975 Transitions

1971-1973 Transitions		Owners 1	Owners 2	Owners 3	Owners 4	Renters 1	Renters 2	Renters 3	Renters 4	Others 1	Others 2	Others 3	Others 4
Owners	1	3707 86.07	222 5.15	64 1.49	244 5.67	18 0.42	4 0.09	2 0.05	1 0.02	34 0.79	1 0.02	5 0.12	5 0.12
	2	270 79.41	46 13.53	6 1.76	18 5.29	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00
	3	0 0.00	0 0.00	0 0.00	0 0.00	42 39.25	12 11.21	13 12.15	9 8.41	13 12.15	5 4.67	9 8.41	4 3.74
	4	0 0.00	0 0.00	0 0.00	514 100.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00
Renters	1	36 2.91	4 0.32	3 0.24	2 0.16	875 70.74	148 11.96	55 4.45	82 6.63	25 2.02	1 0.08	3 0.24	3 0.24
	2	0 0.00	0 0.00	0 0.00	0 0.00	194 57.57	101 29.97	18 5.34	24 7.12	0 0.00	0 0.00	0 0.00	0 0.00
	3	99 54.10	10 5.46	6 3.28	5 2.73	0 0.00	0 0.00	0 0.00	0 0.00	37 20.22	6 3.28	15 8.20	5 2.73
	4	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	279 100.00	0 0.00	0 0.00	0 0.00	0 0.00
Others	1	42 2.59	5 0.31	4 0.25	4 0.25	48 2.96	8 0.49	7 0.43	4 0.25	1238 76.47	158 9.76	31 1.91	70 4.32
	2	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	140 60.61	58 25.11	23 9.96	10 4.33
	3	18 27.27	4 6.06	2 3.03	1 1.52	25 37.88	6 9.09	9 13.64	1 1.52	0 0.00	0 0.00	0 0.00	0 0.00
	4	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	176 100.00

1 - Stay
2 - Move to the same tenure
3 - Move to a different tenure
4 - Die

TABLE 4. TRANSITION PROBABILITIES BY TENURE STATUS 1975-1977

1973-1975 Transitions		1975-1977 Transitions: Owners 1	Owners 2	Owners 3	Owners 4	Renters 1	Renters 2	Renters 3	Renters 4	Others 1	Others 2	Others 3	Others 4
Owners	1	3370 85.95	176 4.49	66 1.68	260 6.63	8 0.20	2 0.05	2 0.05	2 0.05	25 0.64	1 0.03	4 0.10	5 0.13
	2	221 78.93	38 13.57	7 2.50	14 5.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00
	3	0 0.00	0 0.00	0 0.00	0 0.00	32 40.51	14 17.72	8 10.13	9 11.39	4 5.06	4 5.06	5 6.33	3 3.80
	4	0 0.00	0 0.00	0 0.00	789 100.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00
Renters	1	25 2.22	1 0.09	3 0.27	3 0.27	766 67.97	149 13.22	52 4.61	76 6.74	40 3.55	1 0.09	8 0.71	3 0.27
	2	0 0.00	0 0.00	0 0.00	0 0.00	172 64.66	59 22.18	17 6.39	18 6.77	0 0.00	0 0.00	0 0.00	0 0.00
	3	46 47.92	3 3.13	3 3.13	3 3.13	0 0.00	0 0.00	0 0.00	0 0.00	21 21.88	6 6.25	11 11.46	3 3.13
	4	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	400 100.00	0 0.00	0 0.00	0 0.00	0 0.00
Others	1	32 2.22	1 0.07	3 0.21	4 0.28	38 2.63	5 0.35	3 0.21	3 0.21	1151 79.76	104 7.21	26 1.80	73 5.06
	2	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	160 72.73	45 20.45	5 2.27	10 4.55
	3	17 21.25	3 3.75	1 1.25	2 2.50	28 35.00	17 21.25	11 13.75	1 1.25	0 0.00	0 0.00	0 0.00	0 0.00
	4	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	275 100.00

1 - Stay
2 - Move to the same tenure
3 - Move to a different tenure
4 - Die

TABLE 5. TRANSITION PROBABILITIES BY TENURE STATUS 1977-1979

1977-1979 Transitions

1975-1977 Transitions		Owners 1	Owners 2	Owners 3	Owners 4	Renters 1	Renters 2	Renters 3	Renters 4	Others 1	Others 2	Others 3	Others 4
Owners	1	3027 84.96	142 3.99	80 2.25	272 7.63	10 0.28	1 0.03	1 0.03	3 0.08	20 0.56	0 0.00	2 0.06	5 0.14
	2	173 79.36	23 10.55	8 3.67	14 6.42	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00
	3	0 0.00	0 0.00	0 0.00	0 0.00	40 53.33	5 6.67	8 10.67	5 6.67	12 16.00	0 0.00	3 4.00	2 2.67
	4	0 0.00	0 0.00	0 0.00	1085 100.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00
Renters	1	15 1.52	0 0.00	2 0.20	0 0.00	703 71.23	122 12.36	34 3.44	81 8.21	22 2.23	1 0.10	4 0.41	3 0.30
	2	0 0.00	0 0.00	0 0.00	0 0.00	159 68.53	49 21.12	8 3.45	16 6.90	0 0.00	0 0.00	0 0.00	0 0.00
	3	49 54.44	1 1.11	3 3.33	4 4.44	0 0.00	0 0.00	0 0.00	0 0.00	18 20.00	4 4.44	8 8.89	3 3.33
	4	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	511 100.00	0 0.00	0 0.00	0 0.00	0 0.00
Others	1	22 1.61	1 0.07	2 0.15	0 0.00	24 1.75	3 0.22	4 0.29	1 0.07	1105 80.77	99 7.24	21 1.54	86 6.29
	2	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	116 71.17	29 17.79	6 3.68	12 7.36
	3	12 22.22	2 3.70	3 5.56	0 0.00	26 48.15	7 12.96	1 1.85	3 5.56	0 0.00	0 0.00	0 0.00	0 0.00
	4	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	374 100.00

1 - Stay
2 - Move to the same tenure
3 - Move to a different tenure
4 - Die

Therefore, any structural model of the elderly's housing decisions must be able to both incorporate the heterogeneity that exists among households and explain why the elderly become less mobile over time.

2. Household's Decision

When a household considers whether or not to move, the decision involves weighing the gains and the costs associated with moving. The gains may be in terms of location (e.g. weather, proximity to family), "more appropriate" housing, or monetary considerations. The costs include both the observed costs associated with physically moving a household and the unobserved psychological costs associated with leaving a residence and starting anew (these psychological costs include something that has been referred to as an attachment effect, see Venti and Wise(1984)).

An easy way to visualize the way in which a household compares the costs and gains associated with moving is to imagine a household first forming expectations of what life would be like (i.e. what the utility streams would be) both from moving to a different housing situation and from staying at its current residence, and then comparing the differences between these two situations. Whenever the utility from moving is less than it would have been from staying, the difference is considered to be a cost because the household is worse off, and whenever the utility from moving is greater than it would have been from staying, the difference is considered to be a gain. The gains and losses associated with a move and how they change with time are represented by the two shaded areas in Figure 2, where $\hat{U}_s$ is the expected utility level of the household if it stays at its current residence, $\hat{U}_m$ is the expected utility level of a household if it moves, $\hat{T}(x)$ is the expected date of death, and t_o is date at which the household starts the moving process. Note that this graph will look different for each household[10]. The differences between households will come from such things as differing dates of death, the idiosyncratic nature of the unobserved psychological costs, differences in utility functions, and so forth. The effect that each of these differences has on Figure 2 can be seen by shifting around the lines that form the boundaries to the shaded areas.[11]

Not only must the gains and the losses be weighed, but the timing of those gains and losses must also be considered. The time horizon plays an important role here, because while most of the costs are realized initially, the gains accrue over time. Thus, the amount of time until death (length of the time horizon) is very important in the move/stay decision, since the length of the time horizon will indicate how much time a household has to enjoy the gains from a move. Therefore, the decision of whether or not to move must be a comparison of the discounted costs versus the discounted gains.

3. Structural Model

When a household is making a decision as to whether the discounted gains are greater than the discounted costs, the comparison is based on what the household believes about the future. Since one household's expectations about

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[10] It is not necessarily the case that $\hat{U}_m$ is greater than $\hat{U}_s$ for all households. The reason that some households do not move might be because $\hat{U}_m < \hat{U}_s \ \forall\ t$, and there would not be any gains from moving.

[11] For example, how quickly a household becomes integrated into their new community (a difference in psychological costs) is represented by a change in the slope of the transition line between $\hat{U}_s$ and $\hat{U}_m$.

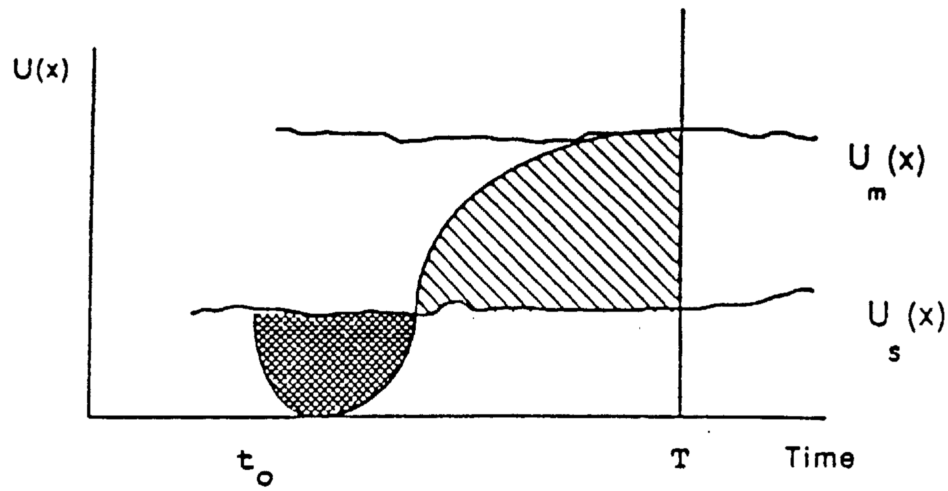

Figure 2

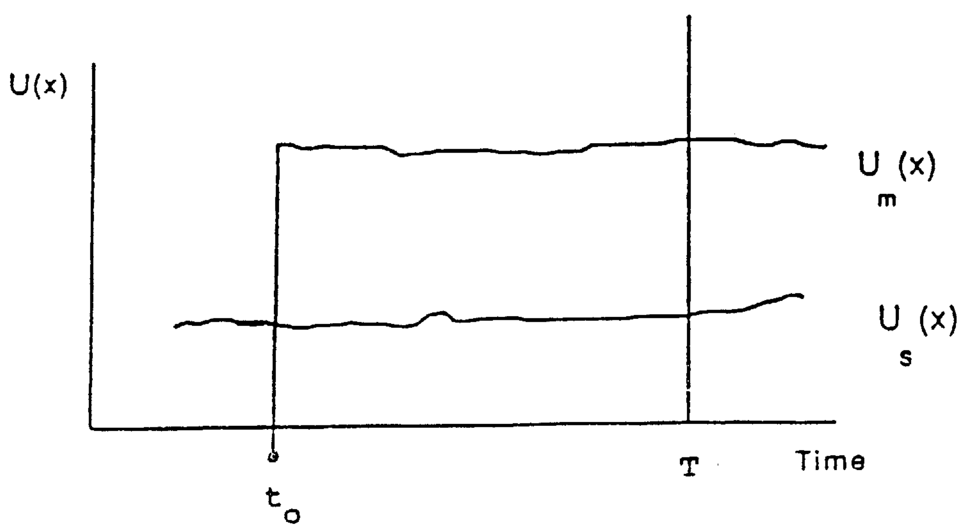

Figure 3

the future may be quite different than another household's, it is very important that the model address the move/stay decision at the household level. Therefore, the decision that an individual household faces as to whether or not to move is made by the household summing up its expected discounted costs and gains from a point t_{io} until the expected death date $\hat{T}_i$. This calculation can be represented by:

$$(1) \qquad E_i \int_{t_{io}}^{\hat{T}_i} (U_m(t) - \hat{U}_s(t)) e^{-r(t-t_{io})} dt > 0$$

where r is the discount rate, and the households are indexed by i (representing the fact that it is the household's expectations about the future that are relevant in the decision process, not what anyone else believes).[12]

While the representation in (1) may be straightforward, the move/stay decision is easier to analyze if it is broken up into the gains and the losses associated with moving. It is also necessary to divide the problem into smaller pieces for a practical reason: it would be impossible to estimate the transition line from $\hat{U}_s$ to the eventual level of $\hat{U}_m$ for all households. Therefore, a discrete approximation is made that still allows for household differences in the costs and gains of moving.

3.1 Costs

The costs associated with moving a household primarily occur immediately

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[12] $\hat{U}_m$ is taken to be the level of utility that would be realized by the household once it began the moving process (i.e. not the level that the household will eventually obtain, but the instantaneous level). Therefore, the costs associated with moving will be represented by the period of time during which $\hat{U}_m$ is less than $\hat{U}_s$.

following a move, with the household facing basically the same moving costs regardless of how long they remain in their new location. The costs of moving at time t are thus represented by the equation:

$$(2) \qquad C_{it} = C_{ot} + C_{1t}Rent_{it} + C_{2t}Other_{it} + B_{1t}\gamma_{it} + \eta_{it}$$

C_{it} is household i's total cost of moving and C_{ot}, the constant term, represents a fixed cost to moving. $Rent_{it}$ is an indicator variable which equals 1 if the household rents their existing living quarters and equals 0 otherwise. Therefore, C_{1t} picks up the difference in the fixed cost of moving between owners and renters. C_{2t} and $Other_{it}$ are equivalent to C_{1t} and $Rent_{it}$, except they apply to the "other" category. γ_{it} is an unobserved, household specific heterogeneity term, and B_{1t} is a multiplicative factor to the household specific effect. Finally, η_{it} is a random disturbance term representing the fact that there may be stochastic deviations from the above representation. The heterogeneity term encompasses many different things: a household's optimism or pessimism of the future; adjustments to the fixed cost of moving term for such things as (i) the difference in the physical cost of moving across town versus across the country[13] or (ii) the difference between those who are "pack rats" and accumulate many things (who therefore have higher moving costs because they have to transport more things) and those who are not. When (2) is used, the enclosed region in Figure 3 represents the gains

[13] This can be seen by realizing that the household who would move across the country is of a different type (i.e. a different γ_{it}) than the household who would only move a short distance. Thus the difference in physical relocation costs would be captured by the different γ_{it}'s multiplying B_1.

from moving, while the costs are just a point mass at t_o.[14]

3.2 Gains

It is well known that households differ in what they think the future will bring. This "feeling of the future" not only makes a difference in the costs of moving (as used in (2)), but it also affects a household's perception of the future utility levels $\hat{U}_s$ and $\hat{U}_m$. Thus, γ_{it} should also be included in $(\hat{U}_m - \hat{U}_s)$. Therefore, the gains from a move are expressed as:

$$(3) \qquad (\hat{U}_m(t) - \hat{U}_s(t)) = U(X_{it};\beta_t) + B_{2t}\gamma_{it} + \epsilon_{it}$$

where: $U(X_{it};\beta_t)$ represents the difference in the utility functions $\hat{U}_m$ and $\hat{U}_s$ as a function of the observed household characteristics X_{it}, B_{2t} is a multiplicative factor to the household specific effect,[15] and ϵ_{it} is a random disturbance term. The exact form of $U(X_{it};\beta_t)$ is discussed later.

3.3 Discounting

To determine the total gain that a household would realize from a move, it is necessary to know not only the amplitude of the new utility level, but also the duration for which the increase would be sustained (i.e. total gain =

[14] The difference in the discounted amounts of costs and gains resulting from specifying that the costs to be all up front and the gains to accrue over time will be absorbed by the coefficients in equation (2).

[15] The utility function can be thought of as being additively separable between a function of characteristics that are observable, and a function of attributes that are common among households yet not observed by the researcher. The heterogeneity term then can be thought of as a representation of the mapping from the unobservables to the real numbers.

B_2 represents the difference in the multiplicative constants to the heterogeneity terms that exist in $\hat{U}_m$ and $\hat{U}_s$. B_2 will not necessarily be zero because γ_{it} will affect $\hat{U}_m$ and $\hat{U}_s$ differently.

(gain/unit of time)*(amount of time)). The length of time that is relevant to the elderly, often referred to as the time horizon, is the expected amount of time until death.

Although a household might be able to make a good prediction of its time horizon by observing those around it in similar circumstances who are (or are not) dying, there still remains a great deal of stochastic variation in the time horizon that the household cannot control. Therefore, a method that resembles an expected value calculation is used to calculate the total gain: the gain for living until time t is calculated, weighted by the probability of surviving until time t, and then all of these weighted gains are summed.[16] Since the gains are calculated from a point t_{io}, the probability of survival that is used must be the probability of living until t conditioned on the fact that t is greater than or equal to t_{io}.

Incorporating the effect of mortality with the explicit representations of the costs and gains of moving, (1) can be rewritten:

$$(4)\quad E_{it}\int_{t_{io}}^{T} -S_i'(t|t_{io}) \int_{t_{io}}^{t} [U(X_{it};\beta_t)+B_{2t}\gamma_{it}+\epsilon_{it}]e^{-r(s-t_{io})}ds\,dt > E_{it}[C_tW_{it}+B_{1t}\gamma_{it}+\eta_{it}]$$

where T is a finite upper bound on lifetimes,[17] $-S_i'(t|t_{io})$ is the conditional probability density function of survival (where the conditioning is upon being

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16 For a discrete example, think of getting 1 util at the beginning of each period. Your gain for living m periods would be m. Now suppose that there are n periods, with the probability of dying in each period being equally likely. Then the total expected gain is: $\Sigma kPr(k) = (n+1)/2$.

17 This T, the upper bound on lifetimes, is not to be confused with T_i, the actual death date of the household.

alive at t_{io})[18], and t_{io} is the age of the household (which has a 1-1 mapping with time) at the time that the move/stay decision is being considered. Notice that for any t in which the inequality in (4) is satisfied, the household will move.

If a household's best prediction about tomorrow is based on things which are known today, and if the distributions of γ_{iy} and of ϵ_{it} are not changing with time, then $E_{it}[U(X_{it};\beta_t)+B_{2t}\gamma_{it}+\epsilon_{it}]$ is not a function of future time. Hence, (4) can be rewritten:

$$(5)\quad E_{it}[U(X_{it};\beta_t)+B_{2t}\gamma_{it}+\epsilon_{it}]\int_{t_{io}}^{T}-S'(t|t_{io})\int_{t_{io}}^{t}e^{-r(s-t_{io})}dsdt > E_{it}[C_tW_{it}+B_{1t}\gamma_{it}+\eta_{it}].$$

Now let the integral expression equal $D(x_{it})$, that is:

$$(6)\qquad D(x_{it}) = \int_{t_{io}}^{T}-S'(t|t_{io})\int_{t_{io}}^{t}e^{-r(s-t_{io})}dsdt.$$

Notice that $D(x_{it})$ is just a discount term, consisting of a household's subjective discounting of the future, weighted by the probability of survival. Since $D(x_{it})$ depends on the characteristics of the household (through t_{io} and $S_i'(t|t_{io})$), it can be thought of as a household specific discount term.

Substituting (6) into (5) simplifies the expression to:

$$(7)\qquad E_{it}[(U(X_{it};\beta_t)+B_{2t}\gamma_{it}+\epsilon_{it})D(x_{it})] > E_{it}[C_tW_{it}+B_{1t}\gamma_{it}+\eta_{it}].$$

18 Since $S(T)=0$ and $S(t_{io})=1$, then for $S(t)$ to be a proper cdf, the ordering of the space needs to be reversed s.t. T is the lower limit and t_{io} is the upper limit. Putting a negative sign in front of $S'(t)$ is equivalent to reversing the order of the limits of integration.

3.4 Stochastic Terms

Since the move/stay decision involves comparing future levels of utility in different states, the household is making a choice under uncertainty. Therefore, the household must make its decision based upon its expectations of the future. To say more about these expectations, it is necessary to be more specific about the unobserved and stochastic parts of (7).

First, consider the household's heterogeneity term γ_{it}. By assuming that γ_{it} has a components of variance structure, then:

$$(8) \qquad \gamma_{it} = \gamma_{io} + \tilde{\gamma}_{it}$$

where the permanent component γ_{io} is household specific and the transitory component $\tilde{\gamma}_{it}$ is a time specific deviation from γ_{io}.[19] Since $\tilde{\gamma}_{it}$ is just a deviation from γ_{io}, it is assumed that the $\tilde{\gamma}_{it}$'s are iid, mean zero, and have a variance of $\sigma^2_{\tilde{\gamma}}$. Furthermore, it is assumed that γ_{io} is distributed with a zero mean and a variance equal to $\sigma^2_{\gamma_o}$, that γ_{io} is independent of $\tilde{\gamma}_{it}$, and that both γ_{io} and $\tilde{\gamma}_{it}$ are normally distributed.[20]

The random disturbance terms, ϵ_{it} and η_{it}, are not only random draws of what the future will bring, but they may also include some unobservable information which is known to the household and will affect the moving decision. It is likely that the underlying processes generating ϵ_{it} and η_{it} will be quite similar (e.g. based on the same unobservable information), yet

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[19] Heckman (1981a) showed that this particular specification of a variance components structure is stationary.

[20] Even though $\tilde{\gamma}_{it}$ is independent in time, γ_{it} will still be correlated over time because of the permanent component γ_{io}. The correlation will be the same between any two periods t and t' and will have a correlation coefficient $\rho = \mathrm{Var}(\gamma_{io})/[\mathrm{Var}(\gamma_{io})+\mathrm{Var}(\tilde{\gamma}_{it})]$.

how the realizations of these processes ultimately affect the household's decision will depend upon the household's type.[21] Thus, ϵ_{it} and η_{it} will be jointly distributed conditioned on γ_{it}, and the following identifying restriction is imposed: ϵ_{it} and η_{it}, conditioned on γ_{it}, have a bivariate distribution with marginal means of zero, contemporaneous correlation ρ, variances of $\sigma^2_{\epsilon_t}$ and $\sigma^2_{\eta_t}$ respectively, and these random disturbances are independent in t.

Since the expectations used in the equations thus far relate to a household's own assessment of the future, these expectations must be conditioned on all of the information available to the household at the time when a housing decision is made. It is assumed that the information set includes a household's knowledge of their type (i.e. a household knows their own γ_{it}), as well as the current realizations of the household's characteristics. This means that the expectations used in the previous equations are actually the conditional expectations $E_{it}[\cdot|X_{it},\gamma_{it}]$. Applying this to (7) yields:

$$(9)\quad (U(X_{it};\beta_t)+B_{2t}\gamma_{it})D(x_{it})+D(x_{it})E[\epsilon_{it}|X_{it},\gamma_{it}] > C_tW_{it}+B_{1t}\gamma_{it}+E[\eta_{it}|X_{it},\gamma_{it}]$$

Computing the conditional expectations and solving for γ_{it} yields:

$$(10)\qquad \gamma_{it} > \frac{C_tW_{it} - U(X_{it};\beta_t)D(x_{it})}{B_{2t}D(x_{it}) - B_{1t}}.$$

Defining the right hand side of (10) as $Z_t(X_{it})$, (10) can be written:

$$(11)\qquad \tilde{\gamma}_{it} + \gamma_{io} > Z_t(X_{it}).$$

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[21] One could imagine that an extraordinarily harsh winter would cause some households to move to a warmer climate, but not affect other households.

Notice that $Z_t(X_{it})$ is a weighing of the costs versus the gains of moving, where the weights are the relative effects of the household heterogeneity on the housing decision.

3.5 Probabilistic Model

Although the components of the household's heterogeneity term are not directly observed, probabilistic statements about household behavior can still be made. As before, these statements are conditional upon the information available to the household at the time a housing decision is made. Using (11) the probability of a household moving at time t, conditioned upon the available information, can be written:

$$(12) \qquad P(\tilde{\gamma}_{it} > Z(X_{it}) - \gamma_{io} | \gamma_{io}) = \Phi\left[\frac{\gamma_{io} - Z(X_{it})}{\sigma_{\tilde{\gamma}_{it}}}\right]$$

where $\Phi(\cdot)$ is a standard normal distribution.[22]

The object of ultimate interest, and what is observed, is a sequence of the household's move/stay decisions.[23] Recalling that with the variance components structure for γ_{it}, the $\tilde{\gamma}_{it}$'s are independent; therefore, the probability of the observed sequence of move/stay decisions can be expressed as:

$$(13) \qquad P(\text{Observed event} | \gamma_{io}) = \prod_{t=1}^{n_i} \Phi\left[\frac{(\gamma_{io} - Z(X_{it}))d_{it}}{\sigma_{\tilde{\gamma}_{it}}}\right]$$

where $d_{it} = 1$ if household i moves in period t and $d_{it} = -1$ if household i

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[22] This is actually the distribution of $\tilde{\gamma}_{it}$ conditioned on γ_{io}, but since $\tilde{\gamma}_{it}$ and γ_{io} are independent, then the conditional is the same as the unconditional.

[23] The LRHS has 5 waves, so there are 32 different sequences possible.

does not move in period t; and n_i equals the number of observed decision periods for respondent i.

Since γ_{io} is unrestricted and allowed to take on any possible value, then the unconditional probability of the observed event is written:

$$\text{(14)} \qquad P(\text{Observed event}) = \int_{-\infty}^{\infty} \prod_{t=1}^{n_i} \Phi\left[\frac{(\gamma_{io} - Z(X_{it}))d_{it}}{\sigma_{\tilde{\gamma}_{it}}}\right] f(\gamma_{io})d\gamma_{io}$$

$$= \int_{-\infty}^{\infty} \prod_{t=1}^{n_i} \Phi\left[\frac{\left(\gamma_{io} + \dfrac{U(X_{it};\beta_t)D(x_{it}) - C_t W_{it}}{B_{2t}D(x_{it}) - B_{1t}}\right)d_{it}}{\sigma_{\tilde{\gamma}_{it}}}\right] f(\gamma_{io})d\gamma_{io}$$

where $f(\cdot)$ is the marginal pdf of γ_{io}.

4. Estimation

Estimation of the unknown parameters in this model requires the specification of the form of $U(X_{it};\beta_t)$ and of $D(X_{it})$, and to make some further identifying restrictions.

4.1 Utility Function

While the housing decision is made jointly by all of the members in a household (i.e. the housing decision is a function of inputs from all household members), the LRHS focuses on information from the respondent. Thus, the decision process modeled here is the housing decision of the household, taken from the respondent's perspective. Nonetheless, because there is altruism in marriage the respondent will incorporate some of the characteristics of the rest of the household in his/her decision. This is done by including some of the characteristics of the respondent's spouse as arguments in the respondent's utility function. The spouse variables can be incorporated easily using a linear form of $U(X_t;\beta_t)$, where the β_t's are constant over time (i.e. $U(X_t;\beta_t) = \beta_o + \beta_1 X_{1t} + \ldots + \beta_k X_{kt}$).

An issue that remains to be addressed, is that the particular realization of a state in the observed sequence may depend upon the previous state. This observation could result from either heterogeneity of preferences among households, or state dependence. The possibility of true state dependence brings up the issues raised in Heckman (1981b); namely, if there is state dependence, then the initial state in the observed sequence must not be taken as given, but rather needs to be estimated because it depends upon previous states not observed by the researcher.[24] Since it is very difficult to distinguish between heterogeneity and state dependence from the data, and since a manifestation of one can often be explained by the other, here it is assumed that what may look like state dependence is actually an indication of the heterogeneity in preferences among households.[25]

4.2 Data

The Longitudinal Retirement History Survey initially interviewed house-

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[24] To accommodate the initial value problem, a generalized distribution, conditioned on γ_{io}, could be used for the first period. The parameters of this generalized distribution would then be estimated jointly with the rest of (16).

[25] For example: one of the reason that a household does not move is because they have high psychological costs associated with change. This would be revealed through the household having a low γ_{io}.

holds in 1969 whose head was between 58 and 63 years old. These households were reinterviewed every two years, with the last interview occurring in 1979. The additional data on the date of death of the respondent was matched, by respondent id, many years after the end of the survey.[26] The population used for estimation was restricted to those who did not have missing values in the years that they were alive.[27] Because people die during the duration of the survey, the dataset is an unbalanced panel, with those that die being observed for fewer decision periods.

Since the interest of the work here is to examine those things that influence a household to move, all of the variables except those calculating a change during a period, take on the value of the variable at the beginning of a period (e.g. a household's tenure associated with a move during the period between 1975 and 1977 would be the tenure reported in 1975). A description of the variables used is as follows:

The OWNER tenure variable equals 1 if the respondent owns his/her current residence either alone or with someone else; 0 otherwise.

The RENTER tenure variable equals 1 if the respondent paid rent (and/or room and board); 0 otherwise.

The OTHER tenure variable equals 1 if: (i) those who answered that either the residence is owned or rented by other family member or partner, or that there was no cash rent for the residence[28]; (ii) those households which had a business facility in their residence at any time during the 10 years of the survey; or (iii) those households who lived on a farm during any of the survey

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[26] The matched death records were provided to me by Paul Taubman.

[27] Many of the missing values occur because the LRHS only contains information on households that were not institutionalized during the survey year.

[28] Of those that pay no monthly rent, over half of them paid a positive amount for utilities and service.

years; 0 otherwise.[29]

The SEX variable equals 1 if the respondent is female; 0 if the respondent is male.

The RACE variable equals 1 if the respondent is white; 0 otherwise.

The MARRIED variable equals 1 if the respondent is married with a spouse currently living at the same residence; 0 otherwise.

The RETIRED variable equals 1 if the respondent reported that his/her retirement status is that of being completely retired; 0 otherwise.

The DISABLED variable equals 1 if the respondent reported that he/she is handicapped or disabled; 0 otherwise.

The SPOUSE WORKING variable equals 1 if the spouse reported that her/his current employment status was either (i) working, or (ii) with a job but not at work; 0 otherwise.

The CHANGE IN MARITAL STATUS variable equals 1 if the MARRIED variables for two consecutive periods were different; 0 otherwise.

The CHANGE IN RETIREMENT STATUS variable equals 1 if the RETIRED variables for two consecutive periods were different; 0 otherwise.

The CHANGE IN HEALTH STATUS--BETTER variable equals 1 if the respondent reported that his/her health is better when compared to his/her health two years earlier; 0 otherwise.

The CHANGE IN HEALTH STATUS--WORSE variable equals 1 if the respondent reported that his/her health is worse when compared to his/her health two years earlier; 0 otherwise.

The CHANGE IN THE NUMBER IN THE HOUSEHOLD variable equal the number of people in the household in the current survey minus the number of people in the household at the time of the previous survey.

The EXCESS REMAINING LIFETIME OF THE SPOUSE variable equals the expected remaining lifetime of the spouse minus the expected remaining lifetime of the respondent; 0 if the respondent is not married. The expected remaining lifetime of an individual was calculated under the assumption that mortality follows Gompertz's Law and equals:

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[29] The reason that those who lived on a farm and those with business in their homes were included in the OTHER category is that their housing decisions are different than the rest of the population (i.e. the decision to more or stay is a joint decision of housing and employment location).

$$(15) \qquad e_x = \frac{1}{a_t}\ln\left[\frac{a_t}{h_t}\right] - X - \frac{1}{a_t}\exp\left[\frac{h_t}{a_t}e^{a_t X}\right]\left(\gamma + \int_0^{\frac{h_t}{a_t}e^{a_t X}} e^{-u}\ln(u)\,du\right)$$

where a_t and h_t are the time-varying parameters of the Gompertz distribution, γ is Euler's constant, and X is the current age of the individual.[30]

The AGE variable equals the current age of the respondent.

The AGE SQUARED variable equals the current age of the respondent squared.

The RATIO OF HOUSING COSTS TO FIXED INCOME variable consists of the annual housing expenditures divided by a household's fixed income.

The EQUITY variable equals the respondents assessed value of his/her home, minus the mortgage on the house, minus any other debt on the house.

The NON-HOUSING WEALTH variable equals a household's assets[31] minus their liabilities.

The means of the variables described above are found in Table 6.

4.3 Mortality

Calculating the mortality of the household is easy when the respondent is single, since there is only one individual involved. However, when the respondent is married, there are two different mortality curves to consider. To be consistent with the decision process being modeled (i.e. from the respondent's perspective), the appropriate mortality consideration for a married respondent is that the joint lifetime of the respondent and spouse will fail within an amount of time t because of the death of the respondent.

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[30] (15) is a different, yet equivalent way of writing (6) of Chapter I.

[31] The asset and liability information used to construct the income and wealth variables came from work that Mike Hurd had done on the original LRHS data.

TABLE 6. MEAN VALUES FOR THE VARIABLES USED IN ESTIMATION

Variable	Mean
Owner	0.646
Renter	0.255
Other	0.099
Sex	0.256
Race	0.078
Married	0.652
Retired	0.444
Disabled	0.281
Spouse Working	0.202
Change in Marital Status	0.022
Change in Retirement Status	0.201
Change in Health Status--Better	0.132
Change in Health Status--Worse	0.300
Change in the Number in the Household	-0.082
Excess Remaining Lifetime of the Spouse	4.758
Age	63.945
Age Squared	4,099.600
Ratio of Housing Costs to Fixed Income	0.649
Equity	14,685.75
Non-Housing Wealth in the Household	77,118.13
$D(x_{it})$	8.670

Under the assumption that mortality follows Gompertz's Law, the relevant mortality for a married household simplifies to the survival curve of the respondent.[32] This simplification, however, does not preclude accounting explicitly for the mortality of the spouse. The spouse's mortality is incorporated into the decision process by including the difference in the expected remaining lifetimes between the respondent and spouse as one of the explanatory variables (X_{it}'s).

Now that the form of $S_i(t)$ is specified, it is possible to write out the explicit form of $D(x_{it})$ using the parameters specified in Chapter I. Thus, allowing for the distributional parameters to vary with time and mortality group, the exact form of the discounting term $D(x_{it})$ is:

$$(16)\quad D(x_{it}) = \int_{t_{io}}^{T}\int_{t_{io}}^{t} \frac{e^{-r(s-t_{io})}\exp\left[\frac{e^{\delta_o+\delta_1 t^*}}{\omega_o+\omega_1 t^*}\left(1 - e^{\omega_o t+\omega_1 t^* t}\right)+\delta_o+\delta_1 t^*+\omega_o t+\omega_1 t^* t\right]}{\exp\left[\frac{e^{\delta_o+\delta_1 t^{**}}}{\omega_o+\omega_1 t^{**}}\left(1 - e^{(\omega_o+\omega_1 t^{**})t_{io}}\right)\right]}\,ds\,dt$$

[32] The proof for the validity of this statement is found in the Appendix. As shown in the Chapter I, the Gompertz assumption is consistent with most actuarial work and seems to fit the data quite well.

$$(17) \qquad = \int_{t_{io}}^{T} \frac{\left(1 - e^{-r(t-t_{io})}\right)\exp\left[\frac{e^{\delta_o+\delta_1 t^*}}{\omega_o+\omega_1 t^*}\left(1 - e^{\omega_o t+\omega_1 t^* t}\right)+\delta_o+\delta_1 t^*+\omega_o t+\omega_1 t^* t\right]}{r\exp\left[\frac{e^{\delta_o+\delta_1 t^{**}}}{\omega_o+\omega_1 t^{**}}\left(1 - e^{(\omega_o+\omega_1 t^{**})t_{io}}\right)\right]}dt$$

where t^*=(survey year-1969)+$(t-t_{io})$, t^{**}=(survey year-1969), and T, the finite upper bound on lifetimes, is set at 125 years. The value used for T is 5 years beyond what the Guinness Book of Records has recorded as the oldest centenarian ever, and no one can logically believe that they will live beyond this date.[33]

4.4 <u>Identification</u>

Some identifying restrictions on the parameters of the model are needed for estimation. First, the variance of the transitory component $\sigma^2_{\tilde{\gamma}}$ is set equal to 1. Next, as can be seen from (10), splitting up the numerator into the two additive parts and taking the first term and multiplying B_{1t}, B_{2t} and C_t by a common constant does not change the value of the term. Therefore, the other identifying restriction needed for estimation is that B_{1t}=1.

5. Results

[33] Since the range of the Gompertz distribution is the positive real line, then the truncation of the survival possibility at 125 requires a normalization of the probability space. This normalization will be that of a conditional probability i.e. $P[x \leq t | t \leq 125] = P[x \leq t]/P[t \leq 125]$. Using the parameter estimates obtained for the Gompertz distribution found in Chapter I, $P[t>125]$ ranges from 1.14e-8 to 4.13e-28, depending upon mortality group.

The results from estimating the model specified in (14) are listed in Table 7. These results were obtained with r set equal to 0.11. It was necessary to impose a value for r because the likelihood surface was so flat in the r dimension that the estimation procedure would not converge when trying to also estimate a value for r.[34]

5.1 Model Estimation

The estimated values for the β's are consistent with the intuition of the model, as those attributes that are associated with a household's resistance to moving have negative coefficients, while the characteristics that relate to the gains from moving (i.e. those that are often found among movers) have positive coefficients.

While it may not be possible to sign all of the β's ex ante, there are some that are clear from the model. One case where the ex ante sign is unambiguous is the age of the head of the household. Age is a good indicator of a household's survival probability (i.e. how long until T_i), which affects what the household believes to be its effective time horizon and how long it would be able to enjoy the gains from a move. Figure 4 shows the percentage of households that move by the age of the respondent. This figure shows that age has a quadratic effect, with a negative coefficient for the quadratic term, and a positive coefficient for the linear term. The estimated coefficients on the age terms shown in Table 7 coincide with what is expected.

The change in marital status and change in retirement status variables can be interpreted as representing an attachment effect. A household that has

[34] Preliminary estimation of the model in (14) for white married males and a variety of values for r resulted in log likelihoods for the different r values that were virtually identical.

TABLE 7. PROBABILITY OF MOVING BY THE ELDERLY 1971-1979

	Estimated Value	Standard Error	Elasticity at Means
σ_{γ_o}	0.5270	0.0333	0.4742
B_2	0.1391	0.0004	12.7607
Cost (constant)	-2.1372	0.2442	15.9061
Cost (renter)	0.8801	0.0535	-1.6721
Cost (other)	0.5568	0.0843	-0.4097
Constant	-0.3965	0.1535	-25.5854
Renter	0.1216	0.0073	2.0037
Other	0.0755	0.0112	0.4815
Sex	0.0053	0.0044	0.0883
Race	0.0011	0.0030	0.0055
Married	-0.0013	0.0006	-0.0538
Retired	0.0007	0.0004	0.0194
Disabled	0.0002	0.0005	0.0028
Spouse Working	-0.0005	0.0005	-0.0071
Change in Marital Status	0.0016	0.0007	0.0023
Change in Retirement Status	0.0020	0.0006	0.0264
Change in Health Status--Better	0.0002	0.0005	0.0019
Change in Health Status--Worse	-0.0002	0.0004	-0.0030
Change in the Number in the Household	0.0004	0.0003	-0.0023
Excess Remaining Lifetime of the Spouse	1.075e-4	5.433e-5	0.0330

Age	0.0046	0.0045	19.0033
Age Squared	-4.545e-5	3.727e-5	-12.0354
Ratio of Housing Costs to Fixed Income	2.686e-4	1.285e-4	0.0112
Equity	3.569e-9	9.276e-9	0.0034
Non-Housing Wealth	-3.477e-10	2.316e-9	-0.0017

Log Likelihood -3009.4007
Number of Observations = 2509

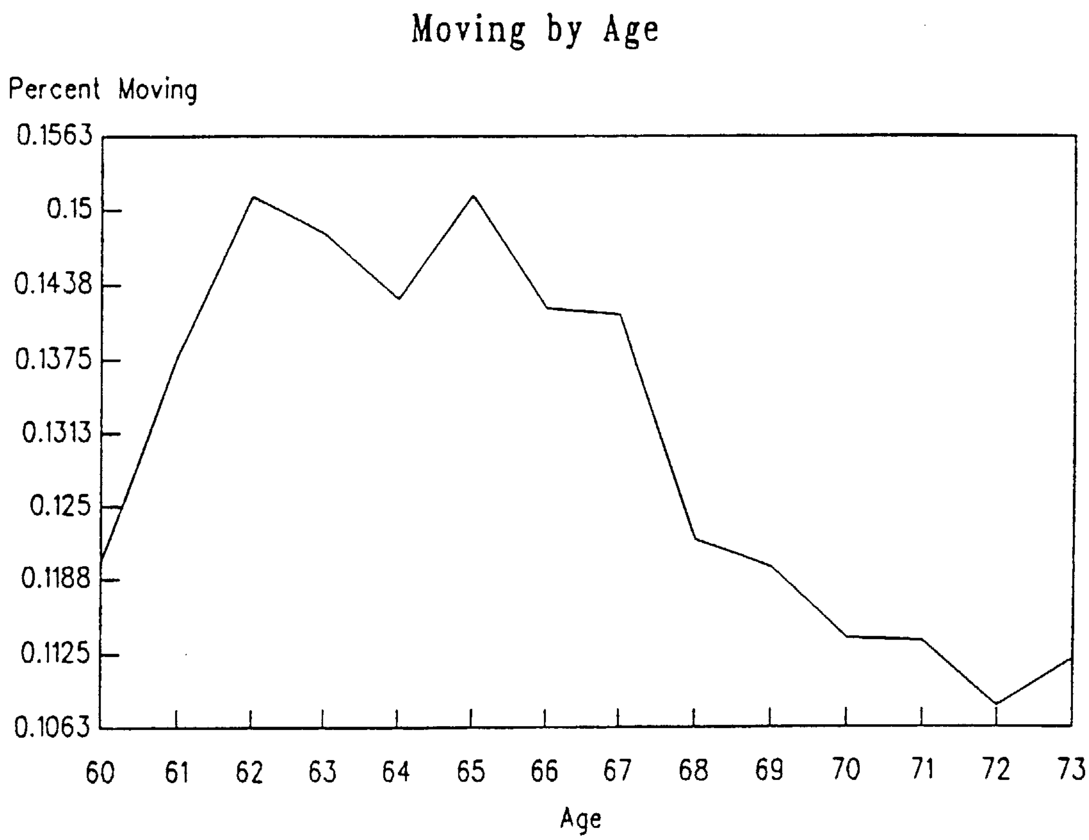
Moving by Age
Percent Moving
0.1563
0.15
0.1438
0.1375
0.1313
0.125
0.1188
0.1125
0.1063
60
61
62
63
64
65
66
67
68
69
70
71
72
73
Age

Figure 4

already retired does not face the restriction of having to live within commuting distance to work, a constraint that may limit the magnitude of the gain in utility associated with a move. Therefore, a retired household is not as "tied down" to a certain area. A move after a change in retirement status might thus represent the effect of relaxing the constraint of having to remain in the same area. A change in marital status (which includes the death of a spouse) might also represent a relaxation of an attachment-type constraint. Another possible, yet different reason for the increased mobility associated with a change in marital or retirement status, is that the household moves to start anew. The estimated positive coefficients for these two variables supports these claims.

As previously mentioned, the housing decision of a household depends not only upon the characteristics of the head of the house, but also upon all members of the decision making unit. The excess expected lifetime of the spouse variable picks up the fact that the actual time horizon for a couple may be different than that of the respondent alone. The estimated positive coefficient on this variable is consistent with the notion that, *ceteris paribus*, the longer a household has to enjoy the gains from a move, the more likely that household is to move.

One possible reason that a household moves is for monetary reasons (e.g. a household may get higher overall utility by redistributing some of its income to other activities). The variable that can be used to examine this reason as a possible explanation for moving is the ratio of housing costs to fixed income variable. One way for a household to decrease its monthly expenditures relative to a fixed income, is to move to a situation with lower housing costs. As the estimated parameter indicates, *ceteris paribus*, a household with a higher ratio of housing costs to fixed income is more likely to move. This positive and significant parameter estimate, coupled with the results below, where the average ratio of housing costs to fixed income decreases after a household moves, strongly supports the argument that one reason a household moves is to redistribute income.

The Average Change in the Ratio of Housing Costs to Fixed Income

	Movers	Stayers
Ratio in 1971 - Ratio in 1969	-0.53	-0.12
Ratio in 1973 - Ratio in 1971	-0.51	-0.09
Ratio in 1975 - Ratio in 1973	-0.04	-0.10
Ratio in 1977 - Ratio in 1975	-0.11	-0.06

Changes in Social Security in 1972 make it possible to perform an in sample test of the hypothesis that many elderly households moved to alleviate liquidity constraints. Although the changes in the Social Security system were enacted in 1972, the following numbers show that the largest average increases in benefits for a LRHS survey period occurred between 1973 and 1975.[35]

Change in Average Outlay per Beneficiary

1971 - 1969	$27.37
1973 - 1971	31.82
1975 - 1973	36.77
1977 - 1975	32.50

The increase in Social Security benefits will clearly increase a household's fixed income, yet the effect upon the ratio of housing costs to fixed income is not as clear because this ratio also depends upon a household's housing costs. A household's housing costs often vary depending on whether or not the

[35] Notice that this is the period during which Supplementary Social Security Insurance (SSI) began.

household moves. Therefore, the analysis of what happens to this ratio must be broken up into movers and stayers. First take the case of the stayers. If housing costs are relatively constant between time t+1 and time t, and fixed income increases for time t+1, then the ratio at time t+1 minus the ratio at time t should be more negative than usual because the ratio at time t+1 decreased. For the movers, the analysis is a little more complicated. If the reason that a household moves is because it is liquidity constrained and forced to move, then this household will not only have a negative value for difference of the ratios between t+1 and t, but will also be at the lower end of the distribution of these values for movers. An increase in fixed income will allow some of the liquidity constrained group to remain in their housing and not move. This will cause a truncation at the lower part of the distribution of values for movers, resulting in a mean that shifts to the right and is more positive than it would have been without the change. The fact that the average values become more negative for stayers and more positive for movers during the period of the greatest increase in the average Social Security outlays supports the hypothesis that many of the households who move do so because of liquidity constraints.

In examining the cost coefficients, it is important to look back at (14) and notice that the net gain from moving is obtained by subtracting the cost terms from the discounted utility terms. Since the cost terms also pick up any immediate gains from moving, then the coefficients on the cost terms should be interpreted as representing an increase or decrease in this net gains; a positive coefficients makes the net gain smaller, whereas a negative coefficient makes the net gain larger. Therefore, while the positive coefficient on the renter dummy taken by itself may seem to imply that renters have greater costs to moving than do owners, when combined with the constant term their sum is negative indicating that the correct interpretation is that owners have larger immediate gains (net of costs) to moving. Although the owners may have more of an immediate gain, the positive coefficient on the renter dummy in the discounted gains equation suggests that renters have greater long term gains from moving. The net result of these two effects can be seen in the following statistics, which were obtained from the model by using the means of all of the variables found in Table 7 except those distinguishing owner/renter/other status.

Probability of Moving

Population	10.4
Owners	6.8
Renters	22.9
Others	14.2

Besides revealing whether the immediate or the long term effects dominate, these statistics can also be used for an informal test of the model. This test is to see how well the implied housing decisions, obtained from the estimated parameters of the model, compare with those when no parametric assumptions are imposed. Since these values give the same ordering as was obtained earlier in the first section,[36] this informal test supports the model.

An issue that was posed in the introduction to this chapter was whether the multiple move phenomenon occurs because some households are intrinsically different in their type (i.e a different γ_{io}) or because their observed characteristics are such that these households frequently gain from moving.

[36] Namely that renters are more likely to move than others, who are more likely to move than owners.

Although the γ_{io}'s are not observed directly, (12) indicates that a household will move if γ_{io} is greater that $Z(X_{it})$, where $Z(X_{it})$ is a function of observable household characteristics. This inequality can be satisfied by relatively large values for γ_{io}, or for relatively small values for $Z(X_{it})$. Since $\gamma_{io} > Z(X_{it})$ when a household moves and $\gamma_{io} \leq Z(X_{it})$ when a household stays, then the value

$$(18) \qquad ZZ = \frac{\max_j[Z(X_{it})|\text{moved in period } j] + \min_k[Z(X_{it})|\text{stayed in period } k]}{2}$$

will give some sort of an average for of breakpoints of $Z(X_{it})$ for a household. The results found in Table 8, divided into categories according to how often a household moves, show that among all but the most frequent movers, the average value of ZZ declines as the mobility of a household increases. Since having a relatively small value for $Z(X_{it})$ is one way that the moving inequality can be satisfied, it is not possible to make any definitive statements regarding whether γ_{io} is on average larger for multiple movers. However, the upswing in the average ZZ for the most frequent movers does suggest that the average γ_{io} for this group is higher than for the other groups.

5.2 Simulation

The results obtained from estimating the model can also be used to see how future changes in government policy will affect the mobility of the elderly.[37] Looking at how mobility changes with a change in Social Security

[37] Since the impact of any current policy will already be incorporated into the parameter estimates (the household has maximized its utility subject to the feasible set), the experiment to perform is to see how changes in policy affect the elderly.

TABLE 8. MEAN VALUES OF ZZ

Category	Number	Mean ZZ Value
Never Moved	1688	1.385
Total Number of Moves = 1	570	1.208
Total Number of Moves = 2	177	1.184
Total Number of Moves = 3	53	1.103
Total Number of Moves = 4	12	1.104
Total Number of Moves = 5	7	1.566
Percentage of Periods Moved ϵ (0,20]	384	1.224
Percentage of Periods Moved ϵ (20,40]	221	1.197
Percentage of Periods Moved ϵ (40,60]	104	1.168
Percentage of Periods Moved ϵ (60,80]	28	1.099
Percentage of Periods Moved ϵ (80,100]	82	1.148
Entire Population	2509	1.323

benefits, a simulation was done where Social Security benefits were increased by 10%. This change will enter in through both the ratio of housing cost to fixed income variable (by altering the size of the denominator) and the non-housing wealth variable. Since Stock and Wise (1988) found that pension plans can adjust to undo any changes in the Social Security benefits that an employee will receive upon retirement, the simulation was done for the 1979 survey, where almost everyone in the survey was retired and the change in Social Security benefits would not effect pension income. The results from this simulation are as follows:

Average Probability of Moving Between 1977 and 1979

	Actual	With Change
Population	12.10	12.08
Owners	7.69	7.68
Renters	22.38	22.35
Others	14.53	14.52

The small change in probability that a given household will move was anticipated because the elasticities in Table 7 were quite small for the two variables affected by this particular change in Social Security. Combining the results from the simulation with those from the actual in sample change reported earlier suggests that while the average probability of moving does not change by very much, there is a group of elderly households at the margin whose housing decisions are significantly affected by a change in their Social Security benefits.

6. Conclusion

While there is a great deal of diversity in the housing decisions of the elderly, the dynamic model presented and estimated in this chapter suggests that there is a cohesive structure that can be used to examine these decisions. The dynamic specification of the model makes it is possible to control for household heterogeneity and to examine various aspects of the elderly's housing decisions that formerly could not be addressed. The results from two informal tests support the model. The first of these tests verifies that the estimated effects of the model nest both the results obtained when no parametric restrictions were imposed upon the decision process and the results from other studies where a structural model was not specified. The second test showed that predictions from the model are consistent with actual changes that occurred in the economic environment during the time span of the LRHS.

An important attribute of the model is the ability to differentiate between the immediate and the future effects that various factors have upon moving. The ability to make this separation reveals that in the tenure status of a household, owners have more of an immediate gain (net of costs) when they move, while the gain to renters is more cumulative over time. The combination of the immediate and long term gains (net of costs) is on average greater for the renters, which is consistent with the observation that renters move more frequently than owners.

In examining the multiple movers, it appears that, with the exception of an extreme group of movers (i.e. those households who moved more than 80 percent of the time periods in which they were observed), the average observable characteristics of the households with multiple moves were discernibly different than those of the households who moved less often. This observation, however, does not allow for the distinction of an unobservable influence upon the probability of moving among these households. In spite of the inability to make this distinction for the other groups, the results do indicate that for the extreme group there is something intrinsically different that is not captured by their observable characteristics.

The effect that a particular characteristic of a household has upon the probability of moving can be easily seen by examining how that characteristic affects the gains and costs associated with moving. For example, those things that decrease a household's expected time horizon, such as aging, decrease the potential gains from a move and thus decrease the probability of moving. One characteristic of the household that effects the time horizon of the household is the remaining life expectancy of the spouse. The significance of this characteristic in the estimation of the model not only reaffirms how important timing considerations are for a household's housing decision, but also verifies the fact that the housing decision is jointly determined by the members in the household.

Since one of the concerns regarding the housing situation of the elderly is whether a household is forced to move because of liquidity constraints, a characteristic of the household that has important policy implications is the household's ratio of housing costs to fixed income. The estimates from the model imply that, *ceteris paribus*, a household with a higher ratio of housing costs to fixed income is more likely to move. This result, coupled with the fact that in the raw data the average ratio of housing costs to fixed income decreased after a household moved, supports the argument that one reason a household moves is because of liquidity constraints. Although the results from a simulation indicate that the average probability of moving does not vary by much when Social Security benefits increase, the results from an actual in sample change in Social Security benefits suggest that there is a group of households at the margin whose housing decisions are significantly affected by a change in their Social Security benefits.

APPENDIX

Let X be a random variable denoting the age of death of an individual, with associated distribution and density functions F(x) and f(x). Define the survival function S(x) as

$$(A.1)\qquad S(x) = 1 - F(x)$$

Then the force of mortality or hazard rate can be written

$$(A.2)\qquad \mu(x) = \frac{f(x)}{S(x)}$$

Two more terms from the actuarial literature that will be useful are ${}_np_x$ and ${}_nq_x$. ${}_np_x$ is the probability that an individual of age x will survive to age x+n, and ${}_nq_x$ is the probability that an individual of age x will die within n years. Formally,

$$(A.3)\qquad {}_nq_x = \Pr\{x < X \leq x+n \mid X > x\} = \frac{S(x) - S(x+n)}{S(x)}$$

$$(A.4)\qquad {}_np_x = 1 - {}_nq_x = \frac{S(x+n)}{S(x)}$$

With this terminology defined, it is possible to proceed with the following claim that will be used later in this appendix.

<u>Claim:</u>

$$(A.5)\qquad \lim_{n\to 0} \frac{{}_nq_x}{n} = \mu(x)$$

Proof: $$\lim_{n\to 0} \frac{{}_nq_x}{n} = \lim_{n\to 0} \frac{\frac{S(x) - S(x+n)}{S(x)}}{n} = \frac{0}{0}$$

applying L'Hospital's Rule yields

$$= \lim_{n\to 0} \frac{-\frac{(-f(x+n))}{S(x)}}{1} = \frac{f(x)}{S(x)} = \mu(x)$$

"Let ${}_nq^{1}_{xy}$ denote the probability that x will die before y and within n years--in other words, that the joint lifetime will fail within n years because of the death of x. This probability may be expressed in definite integral form as

$$(A.6)\qquad {}_nq^{1}_{xy} = \int_0^n {}_tp_{xy}\mu_{x+t}dt$$

since the differential ${}_tp_{xy}\mu_{x+t}dt$ represents the probability that x will die at the moment of attaining the age x+t, y being still alive."[1] Assuming that the mortality of the x and y follow different Gompertz distributions then

$$\text{(A.7)} \qquad S(x) = \exp\left[\frac{h_1}{a_1}\left(1 - e^{a_1 x}\right)\right]$$

$$\text{(A.8)} \qquad S(y) = \exp\left[\frac{h_2}{a_2}\left(1 - e^{a_2 x}\right)\right]$$

Therefore,

$$\text{(A.9)} \qquad {}_np_x = \frac{S(x+t)}{S(x)} = \exp\left[\frac{h_1 e^{a_1 x}}{a_1}\left(1 - e^{a_1 t}\right)\right]$$

$$\text{(A.10)} \qquad {}_np_y = \frac{S(y+t)}{S(y)} = \exp\left[\frac{h_2 e^{a_2 y}}{a_2}\left(1 - e^{a_2 t}\right)\right]$$

$$\text{(A.11)} \qquad \mu(x) = h_1 e^{a_1 x}$$

$$\text{(A.12)} \qquad \mu(y) = h_2 e^{a_2 y}$$

Noting that[2]

$$\text{(A.13)} \qquad {}_np_{xy} = {}_np_x \cdot {}_np_y$$

then combining (A.9-A.13) yields

$$\text{(A.14)} \qquad {}_nq^1_{xy} = \int_0^n \exp\left[\frac{h_1 e^{a_1 x}}{a_1}\left(1 - e^{a_1 t}\right) + \frac{h_2 e^{a_2 y}}{a_2}\left(1 - e^{a_2 t}\right)\right] h_1 e^{a_1 (x+t)} dt$$

Since the argument of the integral is continuous then

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1 Jordan (1967) p.226.

2 "Joint survival requires the individual survival of all the component lives." Jordan (1967) p.192.

(A.15) $$\lim_{n\to 0} {}_n q^{\,1}_{xy} = 0$$

Now the previously proven claim can be applied to derive the force of mortality for the situation where the joint lifetime of x and y fails because of the death of x. Using (A.15) and (A.14) with (A.5) yields

(A.16) $$\mu^{\,1}_{xy} = \lim_{n\to 0} \frac{{}_n q^{\,1}_{xy}}{n} = \frac{0}{0}$$

Applying L'Hospital's Rule and Leibniz's Rule, this expression becomes

$$= \lim_{n\to 0} \exp\left[\frac{h_1 e^{a_1 x}}{a_1}\left(1 - e^{a_1 n}\right) + \frac{h_2 e^{a_2 y}}{a_2}\left(1 - e^{a_2 n}\right)\right] h_1 e^{a_1 (x+n)}$$

$$= h_1 e^{a_1 x}$$

This last expression is the same as (A.11). Therefore, under the assumption that mortality follows Gompertz's Law, the survival curve to use for the case where the joint lifetime of x and y fails because of the death of x is just the survival curve of x.

It should also be noted here that the all of the limits were taken with respect to n and thus the results would still be valid if a_1 and h_1 varied with time.

CHAPTER III

Implications of the Changing Elderly Male Mortality

The current perception that the old are getting older comes from the fact that the life expectancy of the elderly has been increasing steadily. The reality of this perception can be seen by using the information from in Chapter I; the increase in life expectancy for a 65 year old between 1969 and 1979 was 1.1 years for white males, 1.5 years for white females, 1.0 years for non-white males and 1.2 years for non-white females. With the general aging of the population, the continued increase in elderly life expectancy may have important implications in government policies for the elderly; for example, the potential increases in the demand for medical care as the population ages (see Poterba and Summers (1986)).

Another area of possible concern, the financial soundness of the Social Security trust fund, will be addressed in this chapter. Since the financial well being of many elderly is closely linked to the Social Security system, continued changes in mortality may require changes in the Social Security system. In order to judge how the balance of the Social Security trust fund can be affected by changes in elderly mortality, it is necessary to first get a better understanding of exactly how mortality is changing and to identify some of the things that may potentially influence an individual's life span.

Since Chapter I already dealt with how mortality has been changing for the population as a whole, this chapter begins by examining how mortality varies according to various individual characteristics. The first section builds upon the results of Chapter I and focuses on how both observed and unobserved differences in individuals affect mortality. The results of this section are obtained by letting the individual characteristic proportionally adjust the time varying hazard of Chapter I via a proportional hazards framework with unobserved heterogeneity. The magnitude of the effect that each characteristic has upon the mortality of an individual is then estimated by using data from the Longitudinal Retirement History Survey.

Based on the information found in the Chapter I and the first section of this chapter, the actuarial balance of the Social Security trust fund is then examined. The results from this examination suggest that, at a general population level, the life expectancy of a 65 year old over time tends towards the demographic assumptions used by the Social Security Administration which are the most pessimistic for calculating the actuarial balance of the trust fund. The results further indicate that, at the individual level, particular changes in the Social Security system can have secondary effects that work to mitigate some of the gains that the changes were designed to make. For example, while an increase in the retirement age will decrease the number of years that benefits are paid out, the increased retirement age will also increase the life expectancy for those who would have otherwise retired.

1. Covariate Effects on Mortality

Having examined how mortality changes with respect to age, time, sex and race, in Chapter I, the natural question arises as how does mortality vary according to the many other household characteristics, (e.g. marital status) that differ across individuals? To answer this question, this section develops and estimates a formal model of individual mortality.

1.1 Model

The structure of the model follows the simple tree structure shown in Figure 1. There are three possible states for the respondent between successive waves of a survey: (i) the respondent died; (ii) the respondent attritted[1]; or (iii) the respondent continued (i.e. neither (i) nor (ii)). If the probability of dying is p_d and the probability of not attritting is p_s then the probability of state (i) is p_d, the probability of state (ii) is $(1-p_d)(1-p_s)$, and the probability of state (iii) is $(1-p_d)p_s$. These three states are then repeated for either the duration of the survey, or until the respondent ends up in one of the absorbing states, whichever comes first. Since p_d and p_s vary across individuals, these probabilities were quantified as follows. An individual's mortality is assumed to follow Gompertz's Law, with adjustments for individual differences in observed, time varying covariates and unobserved, time invariant heterogeneity. The attrition probability comes from standard probit analysis, which also varies by an individual's covariates.

The adjustment to Gompertz's Law used to calculate p_d employs the proportional hazard framework introduced by Cox (1972). The form of the proportional hazard used here is:

$$(1) \quad \lambda_t(x;z) = \theta\mu_t(x)e^{z\beta}$$

[1] A respondent is considered to have attritted when no information was available on him for that particular wave of the survey and his LRHS identification number was not found in the matching death records for the time period prior to the same wave of the survey. Attrition is a very important aspect of the model for almost as many respondents attritted as died during the 10 year span of the LRHS. One reason for this high attrition rate is that individuals who are institutionalized are not followed while they are in the institution, and unless they die before the next wave of the survey, these individuals would be considered to have attritted.

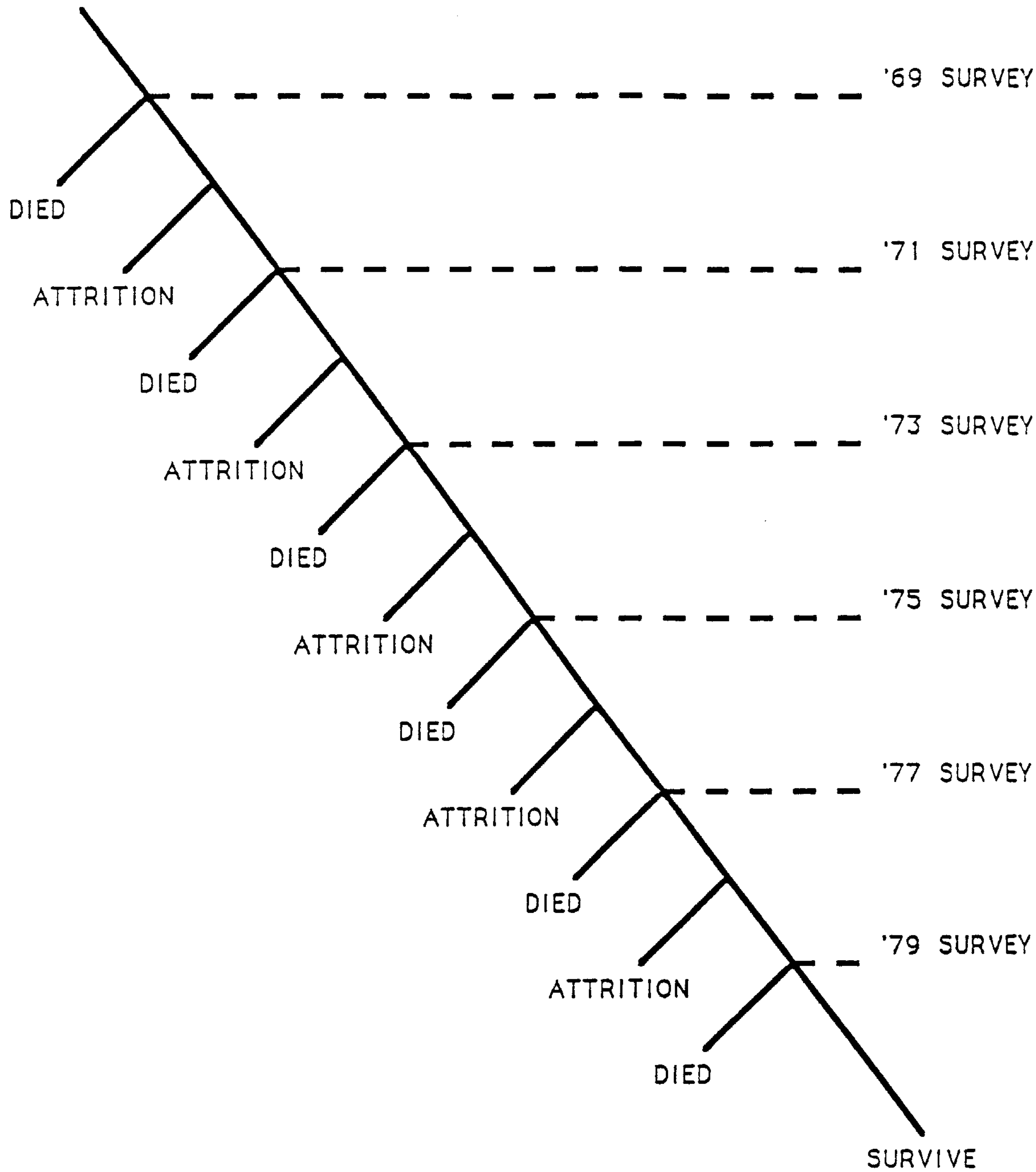
'69 SURVEY
DIED
'71 SURVEY
ATTRITION
DIED
'73 SURVEY
ATTRITION
DIED
'75 SURVEY
ATTRITION
DIED
'77 SURVEY
ATTRITION
DIED
'79 SURVEY
ATTRITION
DIED
SURVIVE

Figure 1

where $\mu_t(x)$ is the baseline hazard for an individual of age x[2], z is a vector of the individual's covariates at time t and θ is an unobserved, individual specific heterogeneity term. As with much of the work in this area[3], θ is assumed to be a gamma variate with a mean of 1 and a variance of σ^2. It is further assumed that θ is independent of both p_s and the covariates.

With the form of the hazard specified, a survival distribution can be calculated. The survival distribution gives the probability that a person will survive beyond age x. Under Gompertz's Law and (1), the survival distribution is parameterized as:

$$(2) \qquad S_t(x) = \exp\left[\frac{\theta\exp(\delta_o+\delta_1 t+z\beta)}{\omega_o+\omega_1 t}\left(1-\exp((\omega_o+\omega_1 t)x)\right)\right]$$

where t is the number of years since 1969. With a survival distribution, it is now easy to calculate p_d. Since longitudinal survey information is only available in discrete intervals, the form of p_d will be:

$$(3) \qquad p_d = \frac{S_t(x) - S_{t+h}(x+h)}{S_t(x)}$$

where h is the number of years between the waves of the survey.

Given the death and attrition probabilities, the likelihood can be formalized:

$$(4) \quad L = E_\theta\left[\prod_{i=1}^{n}\prod_{t=1}^{5}\left(p_{d_{i1}}^{(1-b_i)}\,(1-p_{d_{it}})^{a_{it}b_i}\,p_{d_{it}}^{(1-a_{it})b_i}\,(1-p_{s_{it}})^{(1-c_{it})b_i}\,p_{s_{it}}^{c_{it}b_i}\right)^{d_{it}}\right]$$

---

2 The baseline hazard is indexed by t, since, as was shown in Chapter I, the distributional parameters found in the mortality hazard vary with time.

3 For work on heterogeneity in hazard models of mortality see Manton et. al. (1981,1986), Vaupel et. al. (1979), Yashin et. al. (1985).

where: a_it equals 0 if the individual died between periods t and t+1, 1 otherwise; b_i equals 0 if the individual died between 1969 and 1971, 1 otherwise; c_it equals 0 if the individual attrits between periods t and t+1, 1 otherwise; and d_it equals 1 if the individual is still in the sample (i.e. the respondent has neither died nor attritted by period t), 0 otherwise.

1.2 Data

The data used for the estimation of the covariate effects come from the Longitudinal Retirement History Survey (LRHS) and a linked file on the death date of the respondent.[4] As mentioned in the previous chapter, the LRHS began in 1969 with a random sample of heads of household who were between 58 and 63 years old. These households were reinterviewed every two years for ten years (the last interview was in 1979). Because the sampling frame of the LRHS uses the male of a married household as the respondent, the initial survey does not include any married females. Therefore only male respondents were used in the estimation of (4).[5] The estimating sample was further reduced to include only those who did not have any missing values in the variables used as covariates while they were alive. The final sample contains 5,534 male head of households. Because the data come in discrete intervals (every 2 years) and people are leaving the survey during these intervals for various reasons, all of variables take on the value of the variable at the beginning of a period (e.g.

[4] This file comes from the Social Security files where deaths are recorded as part of the process of issuing death benefits. The file contains an LRHS id number and the month and year of death for that id (through the first few months of 1979). This file was provided to me by Paul Taubman.

[5] Not only is there not a random samples of females, but since the death date of a spouse is only reported by the respondent, the mortality data for the spouses is incomplete (e.g. if the respondent died then there is no way of knowing when the spouse died).

a household's housing tenure during the period between 1975 and 1977 would be the tenure reported in 1975). The various individual characteristics used as covariates are defined as follows:

The RACE variable equals 1 if the respondent is white; 0 otherwise.

The HIGH SCHOOL EDUCATION variable equals 1 if the respondent's highest educational attainment was high school (somewhere in grades 9-12); 0 otherwise.

The COLLEGE EDUCATION variable equals 1 if the respondent attended at least one year of college; 0 otherwise.

The MARRIED variable equals 1 if the respondent is married with a spouse currently living at the same residence; 0 otherwise.

The DIFFERENCE IN LIFE EXPECTANCY variable equals the expected remaining lifetime of the spouse minus the expected remaining lifetime of the respondent; 0 if the respondent is not married. The expected remaining lifetime of an individual was calculated under the assumption that mortality follows Gompertz's Law as specified in (6) in Chapter I.

The HEALTH BETTER THAN OTHERS variable equals 1 if the respondent reported that his health was better than other people of the same age; 0 otherwise.

The HEALTH WORSE THAN OTHERS variable equals 1 if the respondent reported that his health was worse than other people of the same age; 0 otherwise.

The RETIRED variable equals 1 if the respondent reported that his retirement status is that of being completely retired; 0 otherwise.

The DISABLED variable equals 1 if the respondent reported that he is handicapped or disabled; 0 otherwise.

The RENTER (HOUSING TENURE) variable equals 1 if the respondent paid rent (and/or room and board); 0 otherwise.

The OTHER (HOUSING TENURE) variable equals 1 if: (i) those who answered that either the residence is owned or rented by other family member or partner, or that there was no cash rent for the residence[6]; (ii) those households which had a business facility in their residence at any time during the 10 years of the survey; or (iii) those households who lived on a farm during any of the survey years; 0 otherwise. The reason that those who lived on a farm and those with business in their homes were included in the OTHER category is that their housing decisions are different than the rest of the

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[6] Of those that pay no monthly rent, over half of them paid a positive amount for utilities and service.

population (i.e. the decision to more or stay is a joint decision of housing and employment location).

The MEDICARE variable equals 1 if the respondent replied yes to the question: "Do you have Medicare? (Health insurance under Social Security)"; 0 otherwise.

The NUMBER OF LIVING CHILDREN variable equals the number of living children.

The NUMBER OF LIVING SIBLINGS equals the number of living siblings of the respondent.

The NUMBER OF PARENTS STILL ALIVE equals the number of living parents of the respondent.

The LOG(INCOME) variable is the natural log of a respondent's income.

The LOG(WEALTH) variable is the natural log of a respondent's assets minus his liabilities.

The means of the variables listed above are found in Table 1.

1.3 Estimation

Since the baseline hazard in (1) is common to all in the sample and the sample is a random sample of the entire population, then the parameters in the baseline hazard were estimated using population data.[7] The estimation procedure and results for this common part were given in Chapter I.

With the baseline hazard specified, the coefficients on the covariate effects were then estimated by maximizing the likelihood given in (4).[8]

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[7] As was shown in Chapter I, the hazards for white and non-white males do not differ by just a proportionality term. Therefore, separate baseline hazards were used for white and non-white males.

[8] Estimating the covariate effects separately from the baseline hazard is commonly done with proportional hazard models, although usually the baseline hazard is treated as a nuisance parameter and partialled out. For a discussion on estimating proportional hazard models see Kalbfleisch and Prentice (1980).

1.4 Results

The estimation of (4) yields three sets of parameter estimates: (i) σ^2, the variance of the unobserved heterogeneity term; (ii) estimated coefficient values for the covariates describing p_s; and (iii) estimated coefficient values for the covariates of the proportional hazard (used to describe p_d). The estimated values for these three sets of parameters are found in Table 2.

While the focus of this chapter is on the covariates associated with mortality, it is worthwhile to look briefly at the covariates associated with attrition. To determine the effect of a particular covariate, it is important to remember that for p_s, a negative value of the covariate coefficient is associated with a characteristic which is found in individuals who were more likely to attrit. For example, if an individual's health is better/worse than others of the same age, then that individual is less/more likely to need institutional care and is therefore less/more likely to leave the sample. The same argument about the greater likelihood of institutionalization could also be the reason for the negative coefficient on the Disabled covariate. The possible explanation for the negative coefficient associated with the Renter (Housing Tenure) covariate however is somewhat different. The results from Chapter 2 indicate that elderly people who rent their housing as opposed to owning it are more likely to move; hence, a renter may be more difficult to find to reinterview than an owner and therefore more likely to leave the sample.

In contrast with the coefficients for the covariates used with attrition, negative values of the coefficients on the mortality covariates are associated with attributes of those individuals who are more likely to live longer. This is easily seen in the comparative health measure covariates Health Better and

Table 1. Mean Values of the Covariates

Age	63.801
Race	0.066
High School Education	0.429
College Education	0.186
Married	0.870
Difference in Life Expectancy	6.592
Health Better than Others	0.355
Health Worse than Others	0.191
Retired	0.405
Disabled	0.303
Renter (Housing Tenure)	0.160
Other (Housing Tenure)	0.203
Medicare	0.405
Number of Living Children	2.478
Number of Living Siblings	3.298
Number of Parents Still Living	0.135
Log Income	8.491
Log Wealth	1.893

Table 2. Covariate Effects on Male Mortality

	Probability of Attrition	Probability of Death
σ^2	0.1420 (0.1886)	
Constant	1.3707 (0.0585)	0.7107 (0.1098)
Race	0.1943 (0.0616)	----
High School Education	-0.0247 (0.0324)	0.0349 (0.0616)
College Education	-0.0414 (0.0412)	-0.1193 (0.0880)
Married	-0.0566 (0.0524)	-0.4135 (0.0909)
Difference in Life Expectancy	0.0001 (0.0037)	0.0097 (0.0067)
Health Better	0.0207 (0.0316)	-0.3992 (0.0758)
Health Worse	-0.0205 (0.0434)	0.6588 (0.0686)
Retired	0.0229 (0.0341)	0.1824 (0.0653)
Disabled	-0.0719 (0.0359)	0.5612 (0.0658)
Renter (Housing Tenure)	-0.1652 (0.0404)	0.1124 (0.0796)
Other (Housing Tenure)	0.3133 (0.0434)	-0.1782 (0.0762)
Medicare	0.0955 (0.0326)	-0.1784 (0.0675)
Number of Living Children	0.0472 (0.0075)	-0.0144 (0.0132)

Number of Living Siblings	-0.0028 (0.0060)	-0.0288 (0.0116)
Number of Parents Still Alive	----	-0.1636 (0.0882)
Log(Income)	0.0059 (0.0016)	-0.0063 (0.0025)
Log(Wealth)	0.0013 (0.0005)	-0.0023 (0.0009)

Log Likelihood -9,588.93
Number of Observations = 5,534

Health Worse. If an individual's health is better/worse than others of the same age, then that individual is less/more likely to die than others of the same age. The physical differences among individuals is also manifest in the Disabled covariate, with those who are disabled being more likely to die than those who are not. In looking at the family characteristics of the individual, the estimated coefficients coincide with what is commonly observed in the demographic literature--namely that those who are married tend to live longer than those who are not, and at an elderly age, the greater the number of living siblings signals that the individual is more likely to come from "healthy stock" and therefore is less likely to die. Also of interest is to notice that those who are retired are more likely to die than those who are not.

To better understand the magnitude and direction of the association that a particular covariate has with the probability of dying, the results in Table 3 report how life expectancy changes with different values of the binary covariates. Again looking at marriage, if two white males had all of the average characteristics except marital status, then the life expectancy of the married one would be 2.6 years greater than the one who is not married. Likewise, the difference for non-white males would be 2.8 years.

2. Policy Implications

The aging of the general population of the United States has generated concern regarding the financial status of the Social Security trust fund. Because of this concern, on December 16, 1981 President Reagan established the National Commission on Social Security Reform. The Social Security Amendments

Table 3. Effect of the Binary Covariates on Life Expectancy[1]

Variable Name	White Male Var=0	White Male Var=1	Non-White Male Var=0	Non-White Male Var=1
HS Education	11.75	11.52	11.33	11.07
College Education	11.51	12.30	11.06	11.94
Married	9.44	12.01	8.80	11.62
Health Better	10.75	13.41	10.22	13.20
Health Worse	12.49	8.47	12.16	7.78
Retired	12.14	10.95	11.77	10.44
Disabled	12.80	9.26	12.50	8.61
Rent (Housing)	11.77	11.04	11.35	10.54
Other (Housing)	11.42	12.60	10.96	12.29
Medicare	11.18	12.36	10.70	12.01
All variables	11.65		11.21	

[1] All of the covariates except the one being altered were evaluated at their respective means.

of 1983, which improved the actuarial balance between the income and outgo of the trust fund were a direct result of the Commission's recommendations.[9]

To forecast the future prospects of the fund, four sets of projections are used: one is designated as "optimistic" (alternative I), another as "pessimistic" (alternative III), and two are considered "intermediate" (alternatives IIa and IIb). The two "intermediate" alternatives use the same demographic assumptions, but different economic assumptions. The mortality assumptions used by the Commission, which were reported only by sex, along with the estimates from corresponding model from Chapter I are listed in Tables 4 and 5.[10] These tables show that although the Chapter I model estimates are most often between the "intermediate" and the "pessimistic" alternatives, the longer the forecast period, the more "pessimistic" the outlook becomes.

The strength of the downward trend in mortality shown in Tables 4 and 5 can be affected by other things besides medical advances. For example, if people retire earlier than their predecessors, then the results found in Table 3 indicate that the downward trend in population mortality will not be quite as rapid as it would have been had retirement behavior remained the same, since retired individuals tend to die earlier than individuals who are not retired but are otherwise similar. Thus the recent trend towards earlier

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[9] The fund is said to be in close actuarial balance if the income rate is within 5 percent of the cost rate.

[10] While the estimated life expectancies in Tables 5 and 6 that come from the model in Chapter I are separated by race, they are still comparable to the estimate of life expectancy that does not separated by race because the model estimates set an upper and lower bound. However, since there are more whites than non-white in the U.S. population, then the life expectancy for all males (or females) should be closer to the white than the non-white value.

Table 4. Male Life Expectancy

At Birth

Year	Model Estimates White	Model Estimates Non-White	Demographic Assumptions Used Past	I	IIa,b	III
1970	69.9	62.0	67.1	--	--	--
1975	71.2	64.5	68.7	--	--	--
1976	71.4	65.0	69.0	--	--	--
1977	71.7	65.4	69.3	--	--	--
1978	71.9	65.9	69.5	--	--	--
1979	72.2	66.3	69.8	--	--	--
1980	72.4	66.7	69.8	--	--	--
1981	72.7	67.2	--	70.0	70.1	70.3
1982	72.9	67.6	--	70.1	70.4	70.8
1983	73.1	68.0	--	70.2	70.6	71.3
1984	73.4	68.4	--	70.3	70.8	71.7
1985	73.6	68.7	--	70.4	71.0	72.1
1990	74.7	70.5	--	70.9	71.9	74.0
1995	75.7	72.1	--	71.2	72.6	75.3
2000	76.7	73.6	--	71.4	72.9	75.9
2005	77.6	74.9	--	71.5	73.2	76.4
2010	78.5	76.1	--	71.6	73.4	76.8
2020	80.1	78.1	--	71.8	73.8	77.7
2030	81.6	79.7	--	72.0	74.2	78.5
2040	82.9	81.1	--	72.2	74.6	79.4
2050	84.1	82.2	--	72.4	75.0	80.2
2060	85.3	83.2	--	72.6	75.4	81.0

At Age 65

Year	Model Estimates White	Model Estimates Non-White	Demographic Assumptions Used Past	I	IIa,b	III
1970	12.8	12.9	13.2	--	--	--
1975	13.3	13.3	13.7	--	--	--
1976	13.4	13.4	13.8	--	--	--
1977	13.5	13.5	13.9	--	--	--
1978	13.6	13.6	14.0	--	--	--
1979	13.8	13.7	14.3	--	--	--
1980	13.9	13.8	14.3	--	--	--
1981	14.0	13.9	--	14.3	14.4	14.5
1982	14.1	14.0	--	14.4	14.5	14.7
1983	14.2	14.1	--	14.4	14.6	14.9
1984	14.3	14.2	--	14.5	14.7	15.1
1985	14.4	14.3	--	14.5	14.8	15.3
1990	14.9	14.7	--	14.8	15.3	16.3
1995	15.4	15.2	--	14.9	15.6	17.0
2000	15.9	15.6	--	15.0	15.8	17.4
2005	16.4	16.0	--	15.1	16.0	17.8
2010	16.9	16.5	--	15.2	16.1	18.1
2020	17.9	17.2	--	15.3	16.4	18.8
2030	18.9	18.0	--	15.5	16.7	19.5
2040	19.8	18.6	--	15.6	17.0	20.1
2050	20.7	19.3	--	15.7	17.3	20.8
2060	21.5	19.8	--	15.9	17.6	21.5

Table 5. Female Life Expectancy

At Birth

Year	Model Estimates White	Model Estimates Non-White	Demographic Assumptions Used Past	I	IIa,b	III
1970	77.1	69.9	74.9	--	--	--
1975	78.2	72.6	76.5	--	--	--
1976	78.5	73.1	76.7	--	--	--
1977	78.7	73.5	77.1	--	--	--
1978	78.9	74.0	77.2	--	--	--
1979	79.1	74.4	77.7	--	--	--
1980	79.4	74.8	77.7	--	--	--
1981	79.6	75.2	--	77.9	78.0	78.3
1982	79.8	75.6	--	78.0	78.3	78.9
1983	80.0	76.0	--	78.1	78.5	79.4
1984	80.3	76.4	--	78.2	78.7	79.8
1985	80.5	76.7	--	78.3	78.9	80.2
1990	81.6	78.3	--	78.9	80.0	82.5
1995	82.7	79.7	--	79.2	80.8	84.1
2000	83.7	80.9	--	79.4	81.1	84.9
2005	84.8	81.9	--	79.5	81.4	85.5
2010	85.8	82.8	--	79.6	81.6	86.0
2020	87.8	84.1	--	79.9	82.1	87.2
2030	89.7	85.1	--	80.1	82.6	88.3
2040	91.6	85.7	--	80.3	83.1	89.5
2050	93.4	86.0	--	80.6	83.6	90.6
2060	95.2	85.9	--	80.8	84.1	91.8

At Age 65

Year	Model Estimates White	Model Estimates Non-White	Demographic Assumptions Used Past	I	IIa,b	III
1970	17.0	16.0	17.2	--	--	--
1975	17.8	16.6	18.1	--	--	--
1976	17.9	16.7	18.1	--	--	--
1977	18.1	16.8	18.4	--	--	--
1978	18.3	17.0	18.4	--	--	--
1979	18.4	17.1	18.7	--	--	--
1980	18.6	17.2	18.7	--	--	--
1981	18.7	17.3	--	18.8	18.9	19.1
1982	18.9	17.4	--	18.9	19.1	19.5
1983	19.0	17.5	--	19.0	19.3	19.8
1984	19.2	17.6	--	19.0	19.4	20.1
1985	19.3	17.7	--	19.1	19.5	20.4
1990	20.1	18.2	--	19.4	20.3	22.1
1995	20.9	18.7	--	19.7	20.8	23.5
2000	21.7	19.2	--	19.8	21.1	24.2
2005	22.5	19.6	--	19.9	21.4	24.7
2010	23.3	20.0	--	20.0	21.6	25.1
2020	24.9	20.8	--	20.2	22.0	26.1
2030	26.5	21.4	--	20.4	22.4	27.2
2040	28.1	21.9	--	20.6	22.8	28.2
2050	29.6	22.3	--	20.8	23.2	29.3
2060	31.2	22.6	--	21.0	23.6	30.4

retirement would move the model estimates of life expectancy more towards the"intermediate" alternatives.

When examining the financial soundness of the Social Security trust fund, the question arises of whether or not there are other things, besides the general population trend of declining mortality, that might affect the balance of the fund. Specifically, are there changes in the Social Security system that will have an effect on the average mortality of benefit recipients, which will in turn effect the actuarial balance of the trust fund?

This concern can be seen in the suggestion by the National Commission on Social Security Reform to raise the normal retirement age from 65 to 67.[11] The obvious reasoning behind this change was that it will decrease future outgoes because benefits to recipients will be paid out for a shorter period of time, and it will increase funds being paid into the system from the taxes that will be paid in during the additional years of work. The savings however will be somewhat less than the apparent 2 years, because of the "retirement effect" on mortality that was mentioned earlier. As calculated from Table 3, the difference in life expectancy between being retired or not was 1.19 years for white males and 1.33 years for non-white males. Thus, although the 2 year savings is immediate and the potential 1.19-1.33 year change is approximately 11 years in the future, the "retirement effect" is not a negligible effect and should be taken account of when calculating the actuarial balance of the trust fund.

Another potential change in the Social Security system would be to increase benefits by 10 percent. The model and results of this chapter can

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[11] This suggestion was adopted into the Social Security Amendments of 1983.

again be used to examine the effect of this change. Since the coefficient on log income in Table 2 is negative, then an increase in income will be associated with a decrease in mortality. To determine the magnitude of the change, a simulation was conducted wherein Social Security benefits were increased by 10 percent. The resulting change in mortality was very small--the expected lifetime of person with the average characteristics would increase by 1 day. Thus, it appears that ignoring the "income effect" on mortality when calculating the actuarial balance of the trust fund after changing the Social Security benefits by 10 percent will have an inconsequential effect.

Although the effect of only two different potential changes to the Social Security system were analyzed here, they still show that while the Social Security projections account for a generally changing population mortality, there are other effects that will alter the way that mortality is changing in ways that vary from the general mortality projection. These specific variations in mortality may in fact mitigate some of the gains anticipated when changing the Social Security system.

3. Conclusion

Forecasting the future of economic and demographic conditions is indeed a formidable task. However, with an aging population, there is an increased need for the most reliable predictions possible so as to more accurately plan for the future. An important part of this chapter has been to examine both how mortality is changing at the population level and how individual covariates affect mortality at the individual level. With a better understanding of what causes change in mortality, it is then possible to examine how changes in the Social Security system could effect mortality, which in turn could effect the balance of the Social Security trust fund.

The results presented here indicate that when making changes to the Social Security system, there are secondary effects which can negate some of the gains brought about by the initial change to the system. The example used to illustrate this possibility is a change in the normal retirement age. Unless these secondary effects are accounted for when making changes to the Social Security system, the initially proposed changes may not be sufficient to get the desired result.

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