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EXPECTATIONS, LIFE EXPECTANCY AND ECONOMIC BEHAVIOR

Daniel S. Hamermesh

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ABSTRACT

Unlike price expectations, which are central to macroeconomic theory and have been examined extensively using survey data, formation of individuals' horizons, which are central to the theory of life-cycle behavior, have been completely neglected. This is especially surprising since life expectancy of adults has increased especially rapidly in Western countries in the past ten years. This study presents the results of analyzing responses by two groups--economists and a random sample--to a questionnaire designed to elicit subjective expectations and probabilities of survival. It shows that people do not extrapolate past improvements in longevity when they determine their subjective horizons, though they are fully aware of levels of and movements within today's life tables. They skew subjective survival probabilities in a way that implies the subjective distribution has greater variance than its actuarial counterpart; and the subjective variance decreases with age. They also base their subjective horizons disproportionately on their relatives' longevity, and long-lived relatives increase uncertainty about the distribution of subjective survival probabilities.

As one example of the many areas of life-cycle behavior to which the results are applicable, the study examines the consumption-leisure choices of the optimizing consumer over his lifetime. It finds that shortfalls in utility in old age because people's *ex ante* horizons had to be updated as average longevity increased are relatively small. This implies that large subsidies to retirees under today's Social Security system cannot be justified as compensation for an unexpectedly long retirement for which they failed to save.

Daniel S. Hamermesh
Department of Economics
Michigan State University
East Lansing, MI 48824
(517) 355-7349

> Americans are living longer than ever. The lowered death rate, well below what was being projected a few years ago, has enormous ramifications for the Social Security program, insurance actuaries, employers, politicians and economists.[1/]

I. Introduction and Background

Price expectations are central to modern macroeconomic theory. A large amount of empirical work has used survey data to analyze how expectations are formed (see Jonung, 1981; Jacobs and Jones, 1980, for recent examples), and survey results were used even earlier in analyzing inflation (see Turnovsky and Wachter, 1972). Central to the theory of the utility-maximizing consumer is the notion of the horizon. Yet there has been no comparable examination of how individuals form expectations about the horizons over which they maximize. This study begins to rectify this deficiency and uses the results to examine one particular issue of life-cycle behavior.

Several theoretical models have considered more than a fixed length of life: Yaari (1965) examined optimal lifetime consumption plans under the assumption of a known, unchanging vector of survival probabilities; Levhari and Mirman (1977) considered how consumption is affected by a mean-preserving change in lifetime uncertainty; and Arthur (1981) has examined how changing actuarial survival probabilities affect life-cycle maximization. I use the survey data to discover the shape of the entire distribution of subjective survival probabilities in order to examine whether empirical work can rely on current life tables, and whether increases in life expectancy that may motivate theoretical interest are incorporated in individuals' expectations.

Life expectancies of adults in developed Western nations have been increasing at a remarkably rapid pace in the last fifty years, though the maximum attainable age has not increased (Fries, 1980). (Throughout I use the term "life expectancy" to denote expected age at death.) This growth has been especially pronounced in the past decade. Consider the data in Table 1 for whites in the United States.[2/] (These standard measures from life tables show life expectancies based on the mortality rates observed in each year; they do not show the probabilities of survival facing a particular cohort as it ages.[3/]) They present a picture of relatively rapid increases. For example, life expectancy among adult whites age 45 increased by nearly two years in the 1970s, the most rapid gain of any decade since 1910-1920. Similarly rapid increases appear to have occurred in many other developed countries.[4/]

The data from life tables make it clear that the distribution of survival probabilities facing the consumer has been changing rapidly. Whether the typical consumer is aware of these changes and incorporates them into his subjective survival probabilities can be inferred from the survey data. This inference and the results on the shape of the subjective distribution are used in Section IV to examine the extent to which imperfect foresight about cohort life tables reduces utility. These findings suggest the appropriate size of the intergenerational transfer required to maintain consumption of members of a cohort that on average is living longer than it initially expected.

II. The Consistency of Forecasts of Survival

I seek to find how well subjective estimates of life expectancies and survival probabilities meet a particular set of criteria that define consistency, in the sense that they conform to available evidence and are

Table 1

Life Expectancy in the United States, Whites, 1929 - 1980

Age	Year	1929-31	1939-41	1949-51	1959-61	1969-71	1980
0	Male	59.1	62.8	66.3	67.6	67.9	70.5
	Female	62.7	67.3	72.0	74.2	75.5	78.1
25	Male	66.8	68.3	69.9	70.6	70.7	72.7
	Female	69.2	71.8	74.8	76.4	77.4	79.5
45	Male	70.3	70.9	71.9	72.3	72.5	74.3
	Female	72.4	73.9	76.1	77.5	78.5	80.4
65	Male	76.8	77.1	77.8	78.0	78.0	79.1
	Female	77.8	78.6	80.0	80.9	81.9	83.5
85	Male	89.0	89.0	89.3	89.3	89.6	90.4
	Female	89.2	89.3	89.8	89.7	90.5	91.8

Source: Vital Statistics of the United States, 1977, Volume II, Section 5, and unpublished data from the National Center for Health Statistics.

internally consistent. I judge people's beliefs about their own distribution of survival probabilities by the following criteria:

1) Is the individual's subjective life expectancy internally consistent with his subjective probabilities of attaining various ages?

2) Is his subjective survival distribution consistent in shape with actuarial survival distributions, or is it skewed?

3) Actuarial life expectancy is higher for older people; do we then find that subjective life expectancies are higher for older people? Still more important on this issue of demographic consistency, is the representative individual's subjective life expectancy consistent with population averages?

4) Are subjective life expectancies expectationally consistent; that is, do people extrapolate past changes in survival probabilities in forming their own subjective distributions?

5) Is the importance people attach to inheritance and personal characteristics objectively consistent with evidence on their importance?

A. Data

The information used to analyze these five questions was culled from questionnaires sent to two groups of respondents.[5/] The first was a set of 650 white male academic economists. Some were associates of a well-known semi-private organization devoted to empirical economics; most were randomly chosen from the American Economic Association, Biographical Listing of Members, 1978. 63 percent of those surveyed (411 men) returned usable responses. The respondents range in age from 26 to 65 and correspond with a growing population.[6/]

The economists' sample has the attraction that the respondents are familiar with questionnaires and understand expectations and probabilities well; but this is a disadvantage insofar as it leads to responses that are unrepresentative of what a typical consumer would respond. Accordingly, questionnaires were sent to 975 people randomly chosen from the telephone directory of a medium-sized Midwestern SMSA. Among the 47 percent who responded, 363 were white males between ages 20 and 70 (who form the basis from the analysis in this study)[7].

The questionnaire (see the Appendix) provided responses on $(x + e_x^s)$, subjective life expectancy, and on p_{60}^s and p_{80}^s, subjective probabilities of survival to ages 60 and 80 respectively.[8] Additional questions allowed the construction of variables used to test for objective consistency. Included in these are variables reflecting the experience of the consumer's parents and grandparents, and others reflecting his own actions. In the former group is a vector of dummy variables indicating the number of parents and grandparents who died of natural causes before age 60, and another indicating the numbers of survived to age 80. In the latter group are three dummy variables indicating if the person: 1) Smokes more than five cigarettes per day; 2) Engages in vigorous exercise more than once a week; and 3) Had in the past been diagnosed as having an illness that could be fatal.

Table 2 presents sample statistics of the subjective estimates of life expectancy and survival probabilities, and of the actuarial estimates based upon the respondent's age. Most noteworthy among all our results is the excess of $(x + e_x^s)$ over $(x + e_x^o)$, the actuarial life expectancy, in both samples and in subsamples stratified by age. At the very least this suggests that subjective life expectancy reflects life expectancy from today's life tables. That subjective exceed actuarial life expectancies may even imply that the respondents extrapolate past increases in longevity.

Table 2

Means and Their Standard Deviations

	Economists			Random Sample		
Ages	26-39	40-65	26-65	20-39	40-70	20-70
$x+e_x^s$	75.91 (.48)	76.41 (.48)	76.91 (.34)	75.81 (.65)	77.74 (.59)	76.79 (.44)
$x+e_x^o$	73.49 (.02)	75.47 (.09)	74.60 (.07)	73.24 (.04)	76.56 (.15)	74.92 (.12)
p_{60}^s 1/	83.58 (.81)	82.76 (1.17)	83.19 (.70)	80.27 (1.25)	82.05 (2.32)	80.90 (1.15)
p_{60}^o 1/	84.43 (.05)	87.94 (.18)	86.13 (.13)	83.95 (.06)	88.78 (.23)	85.66 (.17)
p_{80}^s	37.83 (1.69)	40.78 (1.82)	39.49 (1.26)	42.21 (1.96)	45.97 (2.37)	44.12 (1.54)
p_{80}^o	33.63 (.02)	36.28 (.16)	35.12 (.11)	33.44 (.02)	38.61 (.33)	36.06 (.22)
AGE	33.66 (.27)	49.76 (.48)	42.71 (.49)	30.61 (.37)	54.59 (.61)	42.76 (.73)
N=	180	231	411	179	184	363

1/ Only persons less than 56 are included.

Though subjective exceeds actuarial life expectancy in both younger and older subsamples, the subjective probability of survival to age 60 is less than the actuarial probability in the former subsamples, and in subsamples of 40-55 year-olds. This reversal hints there may be some internal inconsistency in responses about subjective beliefs on survival. Finally, mean subjective expectations and survival probabilities differ from their actuarial counterparts by very similar magnitudes in the two samples. For example, in the economists sample, $(x + e_x^s) - (x + e_x^o) = 2.31$, while in the random sample it is 1.87 years. These two differences are not significantly different from each other, and the larger figure for the economists is consistent with the sparse evidence on differences in longevity by occupation and education.[9/]

B. Internal Consistency and Skewness

A test for internal consistency is provided by comparing deviations of subjective from actuarial survival probabilities ($[p_{60}^s - p_{60}^o]$ and $[p_{80}^s - p_{80}^o]$) to the deviation of subjective from actuarial life expectancy ($[e_x^s - e_x^o]$). Clearly, some people will be optimistic on subjective probabilities and pessimistic on expectations, and vice-versa; but an inference that the population's expectations are internally inconsistent with their subjective probabilities can be made only if there is a preponderance of optimists about expectancy who are pessimistic about probabilities, or vice-versa. Tests for internal consistency are thus provided by:

$$(1) \qquad ZEi = P(p_i^s < p_i^o | e_x^s > e_x^o) - P(p_i^s > p_i^o | e_x^s < e_x^o), \; i = 60,80 \quad .$$

The statistics ZEi are distributed binomially.

Table 3 presents the estimated ZEi for each sample and for subsamples of younger and older workers. (Men 56+ are excluded because their responses on p_{60}^{s} cannot be used.) Among the economists there is fairly strong evidence of inconsistency between subjective expectations and each of the subjective survival probabilities. Moreover, the inconsistency implies that the respondents' probability distributions are less optimistic than their subjective responses on life expectancy imply. The results are not so strong in the random sample, though some evidence for this same finding exists when the entire sample is used. (Pooling both samples, ZE60 = .137, t = 3.55; ZE80 = .064, t = 1.73.) The results suggest people think about survival probabilities differently from the way they envision what we might equate with the "horizon," our measure e_{x}^{s}. Without knowing whether the complete subjective distribution, or just the subjective life expectancy, motivates behavior, one cannot say which is the more appropriate basis for analyzing life-cycle behavior; our results show, though, that implications for behavior will differ depending on how one models survival probabilities.

Skewness in the distribution of subjective survival probabilities relative to the actuarial distribution can be tested by examining the statistic:

$$(2) \qquad Z6080 = P(p_{60}^{s} < p_{60}^{o} | p_{80}^{s} > p_{80}^{o}) - P(p_{60}^{s} > p_{60}^{o} | p_{80}^{s} < p_{80}^{o}) .$$

Positive (negative) value implies the individual's subjective distributions have more (less) variance than the actuarial distributions of survival probabilities. (Alternatively, it implies that the subjective survival function is flatter (steeper).)

Table 3

Tests of Internal Consistency and Skewness[a/]

	ZE60	ZE80	Z6080
Economists			
26-39	.085	.119	-.045
	(1.19)	(1.72)	(-.64)
40-55	.233	.111	.146
	(3.46)	(1.77)	(2.13)
26-55	.158	.093	.047
	(3.24)	(1.94)	(.95)
Random Sample			
20-39	.128	-.005	.143
	(1.69)	(-.07)	(1.99)
40-55	.091	-.004	.085
	(.95)	(-.05)	(.89)
20-55	.128	-.002	.125
	(2.14)	(-.03)	(2.18)

[a/] t-statistics in parentheses here and in Tables 4-6.

Estimates of (2) are presented in the final column of Table 3. Almost all are positive, and those for the random sample (except for persons 40-55) are significantly positive. (Pooling both samples, Z6080 = .0875, t = 2.22.) The surveys provide some evidence that subjective survival distributions have greater variance then does the actuarial distribution. This result may be unsurprising, in that the subjective distributions are based on each individual's views, while actuarial distributions are based on population experience. It suggests, though, that empirical work involving life-cycle behavior cannot correctly use actuarial survival probabilities, but should at least skew these around $\overset{o}{e}_x$ so that they have greater variance. Thus studies examining life-cycle consumption (eg., Skinner, 1981) will go awry using actuarial measures, for they will overestimate near-term survival and underestimate (compared to people's subjective distributions) survival from 60 until very old age. So too, studies that construct measures of lifetime earnings (eg., Irvine, 1981) to be used in empirical work based in the life-cycle model should use weighted sums of earnings with weights based on actuarial data adjusted for the skewness we have found.

C. Demographic and Expectational Consistency

The sample statistics in Table 2 suggested that the respondents' subjective life expectancy is roughly coincident with today's life tables.[10/] To evaluate the demographic consistency of expectations more formally, consider the equation:

$$(3) \quad x + e_x^s = \beta_0 + \beta_1[x + e_x^o] .$$

If subjective expectations are consistent with today's life table, $E(\hat{\beta}_0) = 0$, and $E(\hat{\beta}_1) = 1$; that is, the subjective mean equals the actuarial mean from current data, and men whose actuarial life expectancy is one year greater respond that their subjective horizon is one year greater.

Tests of these hypotheses can be made using the estimates in columns (1), (2), (5) and (6), in Table 4. The regressions that constrain $\beta_0 = 0$ (columns (1) and (5)) show quite clearly that $\hat{\beta}_1$ is not significantly different from one. However, the standard errors of estimate of the unconstrained equations (columns (2) and (6) are below those of the respective constrained equations. (In each case the constant term is significantly greater than zero at least at the 90 percent level.) This result, along with the observation that $\hat{\beta}_1$ is within two standard errors of one, but more than two standard errors above zero, suggests that people's subjective horizons slightly exceed the actuarial horizon, but that demographic consistency describes differences by age quite well.

I defined expectational consistency as requiring that subjective life expectancy reflects the extrapolation of available information. To formalize this, rewrite (3) as:

$$(4) \qquad x + e_x^s = \beta_0 + \beta_1[x + e_x^o] - \beta_2 \, e_x^o \, [x + e_x^o] \; .$$

If people extrapolate past improvements in life expectancy (see Table 1) as continuing at some positive rate into the future, differences in the subjective horizons among those men who have more years of life remaining (for whom e_x^o is greater) will respond less to differences in actuarial horizons than will differences in $x + e_x^s$ among older men. Thus $\beta_2 > 0$ is equal to the annual rate of increase in life expectancy that the average person in the sample expects. If $\hat{\beta}_2 \leq 0$, we can only infer that people do not believe past trends will continue; whether this is because

Table 4

Determinants of Subjective Life Expectancy: Tests for Demographic and Expectational Consistency

	Economists				Random Sample			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
β_0	----	23.36 (1.34)	----	-34.79 (.59)	----	27.81 (1.89)	----	50.68 (1.17)
β_1	1.02 (2.73)	.71 (3.03)	.99 (2.12)	1.43 (1.93)	1.02 (2.71)	.65 (3.34)	1.00 (.58)	.37 (.70)
β_2			-.00083 (-1.18)	-.00182 (-1.03)			-.00078 (-.31)	.00081 (.56)
$\hat{\sigma}_\varepsilon$	6.861	6.854	6.848	6.853	8.281	8.252	8.264	8.260

they believe that health technology will cease improving, or because of a nonzero subjective probability that a catastrophe will occur, cannot be distinguished from our results.

Columns (3), (4), (7) and (8) present estimates of equation (4) for each sample, with and without β_0 constrained to zero. The estimates suggest very clearly that β_2 is non-positive: The upper ends of the 95 percent confidence intervals around the $\hat{\beta}_2$ from columns (7) and (8) are + .0016 and + .0036 respectively. If the average person (age 43 in each sample) projected trends of the last 40 years, $\hat{\beta}_2$ would have been .041. Even if people projected trends from the 1960's, the decade of least rapid improvements in adult white male longevity, $\hat{\beta}_2$ would equal .013. Clearly, white men do not expect past trends in longevity to continue.[11/] Whether they are aware of these trends and do not consider them, or whether they are not aware, the results suggest that today's life tables are good proxies for people's expectations today. The conclusion that $\beta_1 = 1$ is also supported by the estimates in columns (4) and (8).

D. Objective Consistency

To examine whether individual variation in subjective life expectancies is related to objective characteristics other than life-table data, a vector Z consisting of the dummy variables discussed in part A was added to equation (4). Table 5 shows the estimates of the expanded equation for the two samples. The coefficients on the three dummy variables for old grandparents suggest that each additional grandparent who survived to age 80 adds to the respondent's subjective life expectancy. Conversely, the coefficients on the dummy variables for young grandparents (with the insignificant exception of the second grandparent in the random sample) imply that each additional grandparent who died of natural causes before age 60 reduces the subjective

Table 5

Determinants of Subjective Life Expectancy, Including Z

	Economists	Random Sample
Constant	-2.35	47.79
	(.04)	(1.14)
$x+e_x^o$	.98	.42
	(1.37)	(.80)
$e_x^o(x+e_x^o)$	.0021	-.00077
	(1.27)	(-.54)
Old Grandparents:		
1	.64	.31
	(.77)	(.30)
2	2.07	1.08
	(2.35)	(.91)
3 or 4	2.63	1.46
	(2.55)	(.99)
Young Grandparents:		
1	-2.09	-.65
	(-2.89)	(-.62)
2	-2.43	-.09
	(-2.17)	(-.05)
3 or 4	-5.40	-4.78
	(-1.64)	(-1.17)
Old Parents:		
1	3.01	1.20
	(2.91)	(2.10)
2	5.94	4.01
	(4.26)	(1.81)
Young Parent(s)		
1 or 2	-1.77	-2.70
	(-2.24)	(-2.13)
Smoke	-1.90	-3.48
	(-1.99)	(-2.99)
Exercise	.08	.93
	(.12)	(1.06)
Illness	-3.96	-5.68
	(-3.94)	(-3.96)
$\hat{\sigma}_\varepsilon$	6.39	7.91

life expectancy. Similar responses are observed for the variables representing early and late decedents among parents, with the latter showing particularly strong positive effects.

Despite the pattern of these coefficients, they appear far too large in absolute value given the results of studies on the relation between parents' and offspring's longevity. There is some evidence from twins' studies (see Jarvik et al, 1960) of heritability of a high probability of early death, but evidence on the heritability of longevity beyond this is less clear. Whether the proxy variables represent heredity alone or also reflect omitted environmental factors is unclear. Nonetheless, evidence from regressions of age at death on parents' age at death (Rose and Bell, 1971) indicates that none of the environmental factors excluded from Z, but correlated with parents' and grandparents' longevity, has nearly the effect implied in our estimates. Other things equal, subjective life expectancy of a person whose parents both survived to 80 is 7.71 years (6.71 in the random sample) greater than that of someone whose parents died of natural causes before age 60. This compares to the 2.1-year difference based on the epidemiological evidence as suggested by Sehnert (1975, p. 132).

The effects of personal behavior on subjective life expectancy are somewhat more consistent with the available evidence of their effect on longevity. Persons in both samples appear aware of the detrimental effects of smoking: The coefficients on this variable are quite close to what is suggested by studies of its effects on longevity (see Preston, 1970). Similarly, though the economists attach no importance to exercise, the random sample shows some recognition of its effects.[12/] Finally, the illness variable, essentially a control for a variety of factors, has the expected negative effect.[13/]

The comparisons of these results to evidence from biological studies suggest that the respondents overestimate the importance of their forebears' experience. That they do so is consistent with what Tversky and Kahneman (1974) have called the "availability heuristic," an overreliance on readily available, apparently relevant information in determining one's subjective beliefs on an issue. Objective consistency is only partly satisfied. But people's overreliance on parents' experience in forming their own horizons can enable future research using micro data to examine life-cycle behavior to proxy individual horizons at least partly by the respondents' parents' longevity.

III. The Determinants of Uncertainty About the Subjective Distribution

The discussion in the previous section implicitly dealt with errors in forecasting by the average respondent. The effects of the failure to observe internal and expectational consistency may be small, though, compared to those caused by uncertainty about the subjective probability distribution. Much of the recent literature (Levhari and Mirman, 1977; and Davies, 1981) stresses the role of uncertainty about the horizon, rather than its expected length, in explaining consumption profiles and saving behavior. These considerations suggest that it is worthwhile to try to extract whatever information our sample contains about the determinants of such uncertainty.

For each person below age 56 I fitted the Weibull survival function:

$$P(t) = \exp[-(\frac{t-x}{\Theta_i})^{c_i}] \; , \; t > x \; ,$$

where c_i and Θ_i are parameters, to the responses for p^s_{60} and p^s_{80}.[14/] (This is an exact fit: There are two parameters and two observations on each person.) The fitted c_i and Θ_i are then used to generate a distribution of subjective survival probabilities from which the means, variances, and coefficients of variation of the subjective distributions can be calculated.

The coefficient of variation of the implied subjective survival distribution was regressed against the variables in Z, age, and measures of the variance among each respondent's forebears' longevity. The best-fitting forms of the equation are reported in Table 6. In unreported regressions the variables representing smoking, exercise and illness had t-statistics below .7; measures of the variance of forebears' longevity did not fit as well as the longevity variables themselves; and continuous measures of the number of parents or grandparents dying young or surviving to age 80 produced lower $\hat{\sigma}_e$ than did the vectors of dummy variables included in Table 6. 288 of the 337 economists under age 56 were used in this analysis, as were 225 of the 276 white men under age 56 in the random sample.[15/]

The most striking result is the decline in the variance of the subjective distribution with age; the decrease is observed whether or not the equation is conditioned on forebears' longevity. This result should not be surprising: Older people in the subsamples have avoided early death, a low-probability event that greatly increases the variance of observed lifetimes. The finding implies that the demand for life insurance will be greater among younger persons in a risk-averse population. It also means that one should not, as Davies (1981) has, treat the effects of aging in a life-cycle model independently of assumptions about uncertainty

Table 6

Determinants of Subjective Uncertainty About Survival

	Economists		Random Sample	
	(1)	(2)	(3)	(4)
Constant	.239	.240	.283	.308
	(8.81)	(7.89)	(8.93)	(8.37)
Age	-.0012	-.0016	-.0019	-.0031
	(-1.77)	(-2.14)	(-2.25)	(-3.26)
Number of:				
Old Grandparents		.011		.011
		(2.35)		(1.45)
Old Parents		.015		.064
		(1.21)		(2.52)
Young Grandparents		-.0029		-.0085
		(-.40)		(-.74)
Young Parents		-.0058		.018
		(-.46)		(.88)
$\hat{\sigma}_{\varepsilon}$	.0859	.0851	.1194	.1175
N	288		225	

of survival.

The results in columns (2) and (4) show fairly clearly that men with long-lived forebears are more uncertain about their subjective survival distribution, though men with forebears who died young are not less uncertain. Coupled with the results in Table 5, these findings indicate that having early decedents among one's forebears shifts the subjective distribution to the left and narrows it (since the variance must decrease with reduced mean if the coefficient of variation is unaffected); having late decedents shifts it rightward and widens it. Thus parents' longevity is partly a proxy for increased uncertainty about survival as well as for a more distant horizon.

IV. Intergenerational Transfers and Changing Subjective Horizons

The findings on the horizon and its uncertainty can be used to analyze a number of specific issues in life-cycle behavior. In this section I consider two of those: How changes in the subjective distribution affect paths of consumption and labor supply, and the extent to which a path based on subjective probabilities such as those implied by our results differs from one implied by perfect foresight about survival probabilities. Examination of the first issue enables us to extend previous work on the effect of differences in the horizon and uncertainty about it on lifetime consumption (see, eg., Levhari and Mirman, 1977). Consideration of the second point allows the calculation of the size of intergenerational subsidies that would be required to maintain utility levels in an older population that faced unexpected increases in longevity. Since one justification for subsidies through social insurance is the desire to avoid having older persons' consumption fall sharply because they could not plan well, the calculations provide estimates of the size of the subsidy that is justified by this concern.[16]

The simulation model builds on the work of Yaari (1965). I make various assumptions about: 1) The degree of perfection in capital markets (whether there exist actuarially fair annuities); 2) The relative importance of consumption and leisure in a utility function that is strongly separable in these arguments; and 3) The elasticity of utility with respect to increases in consumption or leisure. I assume a generalized isoelastic utility function:

$$(5) \qquad U = C^{1-\delta}/1-\delta + aL^{1-\delta}/1-\delta \quad ,$$

where C is consumption in any period; L equals one if the person is retired, zero otherwise; and δ and a are parameters indicating the elasticity of marginal utility to its arguments and the relative weights of consumption and leisure.[17] This simple formulation produces tractable optimal lifetime consumption and labor supply paths.

I assume that at each point in time the consumer maximizes:

$$(6) \qquad V(t) = \int_t^T P(t,\tau)U(\tau)e^{-r(t-\tau)}d\tau \quad ,$$

where t is his current age; T is the maximum attainable age; and the vector $P(t,\tau), \tau \geq t$, is his forecast of the probability of survival to age τ, with $P(t,t)=1$. The simulations deal with white males; I assume the typical person is age 20 in 1930 (by assumption, t=1) and follow his utility-maximizing choices of C_t and L_t from 1930 through 1979. For each set of assumptions about the triad of parameters (δ,a,ρ) the model is simulated under four sets of assumptions about the forecasts of survival probabilities:

P_1--The typical consumer in this cohort assumes that $P(t,\tau)$, given survival to age t, is what it was at t=1. P_1 thus embodies completely rigid forecasts; the consumer neither extrapolates past changes in survival probabilities nor updates his forecasts based on recent changes in those probabilities.

P_2--The consumer forecasts his chances of survival from time t to time τ based upon the life tables for year t. His forecasts are constantly updated, but he does not expect continuing improvements in the life table. This assumption is based on the evidence in Section II of demographic consistency, and on the finding that people do not extrapolate past improvements in the life tables.

P_3--The consumer forecasts based on e_x^o from the life tables at time t, but his subjective survival probabilities are inconsistent in shape with actuarial data, being flattened as I demonstrated in Section II.[18/] His forecasts are skewed and constantly updated, consistent with all the evidence in Section II. P_3 is a mean-preserving spread of P_2.

P_4--The consumer has perfect foresight; at any time t he knows with certainty what $P(\tau, \tau+k)$ will be, for all $\tau > t$. Essentially the consumer knows *ex ante* what the cohort life table for his cohort will be.[19/] The distinction between these assumptions is not trivial: For example, using survival to age 85 (t=66), P_1 (1,66)=.085, but P_4(1,66)=.166.

Since the focus is on retirement, I assume that L=0 for $t \leq 35$; that L=1 for $t \geq 56$; and that L cannot switch from one to zero. (These assumptions reduce computing costs tremendously and correspond fairly closely to reality.) Annual earnings are assumed exogeneous, and the only source of income is past savings or current borrowing if L=1. Earnings are assumed to follow a typical inverted-U path, and that path is assumed to to shift upward over time with the growth in real disposable income per capita that took place between 1930 and 1979.[20] The typical consumer is assumed to be fully aware of the life-cycle pattern of earnings but does not extrapolate past improvements in real incomes. (The results do not differ qualitatively if the consumer extrapolates the past ten years' rate of change in per capital income.)

I make two polar assumptions about the nature of capital markets: 1) No borrowing is possible, so that wealth is always nonnegative; and 2) There is a perfect annuities market, so that the expected value of wealth at T is zero, given a particular matrix P_i assumed in the simulation.[21] Given a vector L, and a particular isoelastic utility function, the optimal lifetime consumption profile at $\tau > t$ under the first assumption is:

$$(7)\qquad C(\tau) = C(t)\exp\{\frac{1}{\delta}[(\tau-t)(r-\rho) + \int_t^\tau \frac{\dot{P}(t,s)}{P(t,s)}\,ds]\} \quad ,$$

subject to the constraint that:

$$(8)\qquad W(\tau) = W(t)e^{r(\tau-t)} + \int_t^\tau [L(s)E(s)-C(s)]e^{r(\tau-s)}ds \geq 0,\ \forall\tau \geq t \ ,$$

where E(s) are earnings in period s. The consumer cannot plan a consumption profile that would require negative net worth at any future time. Under the assumption that there is a market in actuarially perfect annuities (see Yaari, 1965), the optimal consumption profile at $\tau > t$, given a particular path of future L, becomes:

$$(9)\qquad C(\tau) = C(t)\exp\{\frac{1}{\delta}[r-\rho][\tau-t]\} \quad ,$$

with the side constraint on probabilistic terminal wealth:

$$(10)\qquad W(T) = \int_t^T \{\exp[-\int_t^\tau [r - \frac{\dot{P}(t,s)}{P(t,s)}]ds]\}[L(\tau)E(\tau) - C(\tau)]\,d\tau = 0 \quad .$$

Under the assumption of no borrowing, incorrect forecasting of survival probabilities is likely to lead to a greater departure of actual from *ex post* (perfect forecasting) utility, for the existence of annuities markets will enable the consumer to protect himself against the possibility of unexpectedly long lifetime.

I simulate the optimal lifetime consumption and retirement paths for $1 \leq t \leq 50$, for both assumptions about capital markets, and for various assumptions about the triad (δ, a, ρ). These parameters are chosen in most cases so that the optimal retirement age, R, under assumption P_1 is such that $35<R<56$. r is set equal to .03 in each simulation. For $t>50$ C and L are those projected at $t=50$. The model is simulated by taking the vector $L(\tau)$, $\tau=t,\ldots T$, as given, and solving for optimal consumption according to (7) or (9) with side constraints (8) or (10). All feasible vectors $L(\tau)$ are searched, and the optimal path is that for which the probabilistic utility function (6) is maximized.

Tables 7 and 8 present the results of the simulations under both assumptions about the nature of capital markets, for six combinations of parameters δ, a, and ρ. Two findings stand out immediately from consideration of the optimal retirement age under the differing assumptions about perceptions of survival probabilities: 1) Moving from P_1 to P_2 to P_4, there are only tiny changes in R. Apparently, under the assumptions that condition the utility function, most of the increase in longevity that occurs is consumed optimally in the form of leisure near the end of the life cycle. 2) Comparing R under P_2 and P_3 in Table 7, we see that introducing a mean-preserving spread into subjective survival probabilities at each point in the life cycle leads in several cases to substantial postponement in the age of retirement. However, as can be seen by comparing

Table 7

Optimal Retirement Age, and Equalizing Percentage Increase in Consumption, No Borrowing

(δ, a, ρ)	Retirement Age, R + 19	Equalizing Increase in Consumption Cohort-Weighted		Unweighted	
		$\sum_{55}^{69}$	$\sum_{70}^{101}$	$\sum_{55}^{69}$	$\sum_{70}^{101}$
(.6,.9,.01)					
P_1	66	3.97	27.87	4.47	49.40
P_2	65	1.46	7.29	1.73	8.22
P_3	69	16.82	-11.14	19.25	-25.38
P_4	65				
(.7,.6,.01)					
P_1	64	.97	32.17	1.31	51.24
P_2	64	1.54	6.74	1.78	7.17
P_3	65	7.72	12.89	6.32	1.83
P_4	64				
(.75,.6,.03)					
P_1	58	3.21	34.95	3.69	53.65
P_2	58	.43	5.40	.68	5.69
P_3	59	8.91	3.84	8.10	-7.73
P_4	58				
(.6,1.1,.03)					
P_1	62	5.71	28.02	5.49	48.92
P_2	61	.80	6.42	1.04	7.22
P_3	65	18.71	-14.16	18.71	-25.79
P_4	61				
(.8,.55,.08)					
P_1	56	2.96	33.60	3.33	52.18
P_2	56	.89	4.63	1.07	4.86
P_3	57	2.04	-8.41	.18	-20.35
P_4	56				
(.8,.45,.08)					
P_1	75	-1.07	11.26	-1.29	28.19
P_2	75	-.02	-.41	-.02	-.43
P_3	75	.02	-1.17	-.10	-12.79
P_4	75				

Table 8

Optimal Retirement Age, and Equalizing Increase in Consumption, Perfect Annuities Markets

(δ,a, ρ)	Retirement Age, R + 19	Equalizing Increase in Consumption			
		Cohort-Weighted		Unweighted	
		$\sum_{55}^{69}$	$\sum_{70}^{101}$	$\sum_{55}^{69}$	$\sum_{70}^{101}$
(.6,.9,.01)					
P_1	64	-3.92	-1.27	-3.92	-1.27
P_2	64	.19	3.94	.37	3.95
P_3	64	.01	2.78	.11	2.78
P_4	64				
(.7,.6,.01)					
P_1	61	-6.18	7.60	-5.64	7.60
P_2	62	.77	4.10	.89	4.10
P_3	62	0	3.39	.12	3.39
P_4	62				
(.75,.6,.03)					
P_1	58	-.17	2.89	.08	5.35
P_2	58	1.05	4.93	1.24	4.93
P_3	58	.37	5.25	.63	5.25
P_4	58				
(.6,1.1,.03)					
P_1	59	-4.32	13.85	-3.12	13.85
P_2	60	.73	4.61	.92	4.61
P_3	60	.11	3.10	.16	3.10
P_4	60				
(.8,.55,.08)					
P_1	75	-5.33	-6.92	-5.43	-7.13
P_2	75	-1.29	-.83	-1.29	-.83
P_3	75	-4.03	-5.44	-4.13	-5.44
P_4	75				
(.8,.45,.08)					
P_1	75	-5.33	-7.11	-5.43	-7.18
P_2	75	-1.29	-.83	-1.29	-.83
P_3	75	-4.03	-5.49	-4.13	-5.49
P_4	75				

the results in Tables 7 and 8, this result depends entirely on the effect of uncertainty on the assumption that the consumer's net worth be non-negative. When we assume a perfect market for actuarial annuities, the retirement age is not affected by an increase in uncertainty of the size we assume.

The final four columns in the Tables are based upon a comparison of utilities under assumptions P_1 through P_3 to that attained under P_4. The elasticity of utility with respect to consumption in (5) is:

$$\partial \ln U_t / \partial \ln C_t = C_t^{1-\delta} / U_t \quad .$$

The numbers are calculated as:

$$x = 100 \; [1 - \sum_{t=N_1}^{N_2} Up_i(t) / \sum_{t=N_1}^{N_2} Up_4(t)] / [\sum_{N_1}^{N_2} Cp_i^{1-\delta}(t)/Up_i(t)] \; ,$$

where the N_i are arbitrary ages. They show the percentage increase in consumption necessary in each period to equalize the sum of utilities under assumption P_i, i=1,2,3, to that under P_4. The calculations are presented separately for the consumption increments required to equate utility streams during early older years, ages 55-69, then during later older years, ages 70-101.

I present results separately with and without weights implied by the number of persons surviving in the cohort of men age 20 in 1930. The first set of equalizing increases in consumption implicitly weights all persons in the cohort equally, while the second set puts a higher weight on the utility of those who survive longer. Which of these two sets of results deserves more attention depends on one's purposes: If we are concerned with the average welfare of the whole cohort, the first set of results is the important one, for it recognizes that the cohort declines in size as it ages. If we are more concerned about maintaining incomes of older persons, the second set of estimates should be focussed upon, for it gives greater weight to those who survive longer.

The most striking result in the last four columns is the relatively small percentage increase in consumption required to equate the utility stream to that obtained with perfect foresight. Only when no borrowing is possible and forecasts of the probabilities of survival are completely rigid does utility in the later part of the life cycle differ substantially from that attainable under maximization with perfect foresight. If people forecast in ways implied by the results in Section II, the shortfalls in utility are very small.

It seems quite fair to conclude, subject to the restrictions of the assumptions in our maximization problem, that rapid increases in longevity in the past fifty years did not result in persons who survived longer than they initially forecast consuming much less in old age than if they had known _ex ante_ how survival probabilities would change. Though the increases were swift by historical standards, they were slow enough to allow the typical consumer _who updates forecasts_ to adjust consumption and saving sufficiently to come fairly close to an _ex post_ optimum. Munnell (1977) suggests that in the early 1970s the intergenerational subsidy implicit in Social Security could have been half of benefits. With replacement rates of 50 percent, this far exceeds the rates implied by Tables 7 and 8. The results suggest that the subsidy cannot be justified as compensation to a generation whose average longevity exceeded its initial expectations.

The close approximation of utility in old age under P_2, P_3 and P_4 suggests that people form their subjective horizons in ways consistent with optimizing behavior in the presence of information costs. It is quite easy to acquire information on current life tables. I showed in Section II that people use that information when they form their expectations, and I demonstrated here that those expectations are nearly sufficient to allow the attainment of an *ex post* actuarial lifetime utility maximum. People do not make the more complex calculations necessary to predict changes in survival probabilities; but their failure to do so does not, as we have seen here, reduce their lifetime utility much below what it would have been had they made these calculations.

V. Conclusions and New Directions

Increases in life expectancy in the U.S. and other Western countries represent as important a demographic/labor-market change as do the often studied 1950's baby boom and the increased labor-force participation of married women. This paper has examined awareness of this demographic change by individuals as they project their life expectancy, and whether their projections are internally consistent and based upon determinants that coincide with the evidence of epidemiological and demographic studies. I find that they do not extrapolate when they determine their subjective horizons, though they are aware of levels of and improvements within current life tables. People skew subjective survival probabilities in a way that implies the subjective distribution has greater variance than its actuarial counterpart; and the subjective variance decreases with age. They base their subjective life expectancies disproportionately on their relatives' longevity; and long-lived relatives increase uncertainty about the subjective distribution of survival probabilities.

The findings on the subjective horizon were used to examine the consumption/leisure choices of a utility-maximizing consumer over his lifetime. Shortfalls in utility in old age because of skewed or imperfect forecasting of survival probabilities were found to be relatively small. This implies that large subsidies to retirees under today's Social Security system cannot be justified as compensation for an unexpectedly long retirement for which they failed to save.

In Sections II and III I discussed some uses of the results in modifying theoretical and empirical work on life-cycle behavior. A large number of other implications arise from these findings. The implied skewness of the subjective survival distribution means that actuarially fair insurance and annuity schemes will have nonneutral behavioral effects. The extent of the distortion can be lessened, and sellers of such plans can undercut their competitors, by offering plans based on skewed survival distributions that have the same expected value as their actuarial counterparts. Also, in a world with mandatory or customary retirement at age 65 or 70, skewed survival probabilities will lead people to invest more than otherwise in assets whose returns are concentrated during retirement rather than during the person's working years.

The existence of demographic consistency and the failure of people to extrapolate changing life tables supports the use of current life expectancy in cross-section studies of aggregate savings (see, eg. Feldstein, 1977). In these, though, an average of life expectancies by age weighted by the age distribution of the population is the appropriate proxy for the average horizon. Time-series studies of savings and labor supply should account for increasing life expectancy and its transformation into the subjective horizon that determines behavior. If the results in Section IV are correct, and greater longevity is consumed mostly as leisure, failure to include the increasing horizon in such studies will bias estimates of the effects of any other variable containing a trend.

Changing distributions of subjective survival probabilities must be modelled in studies of bequest behavior. Unplanned bequests (see David and Menchik, 1981) will be lower when, as our results show, people fail to forecast reductions in mortality. Empirical work that examines bequests in different population cohorts must also consider how they are affected by changing mortality experience and its relationship to subjective horizons.

In any area of economic behavior, where length or uncertainty of the horizon affects decisions, secular changes in longevity must be considered. However, modelling those changes cannot be done mechanically; as I have shown, they are processed into subjective survival decisions only incompletely, and in ways that appear fairly complex. Empirical studies that model these sorts of behavior ignore changing life expectancy and its effects on subjective survival probabilities at the expense of realism, and with the price of possibly incorrect behavioral implications. Theoretical studies that treat actuarial data as directly motivating behavior miss much of the potential richness of their models if they ignore how those data are transformed into the subjective probabilities that are the proximate determinants of the phenomena under study.

REFERENCES

W.B. Arthur, "The Economics of Risks to Life," American Economic Review, 71 (March 1981), 54-64.

Martin David and Paul Menchik, "The Effect of Social Security on Bequests," MSU Econometrics Workshop Paper, No. 8007, April 1981.

James Davies, "Uncertain Lifetime, Consumption and Dissaving in Retirement," Journal of Political Economy, 89 (1981), 561-577.

Louis Dublin, Alfred Lotka and Mortimer Spiegelman, Length of Life, New York: Ronald Press, 1949.

Regina Elandt-Johnson and Norman Johnson, Survival Models and Data Analysis, New York, Wiley, 1980.

Martin Feldstein, "Social Security and Private Saving: International Evidence in an Extended Life-Cycle Model," in M. Feldstein and R. Inman, The Economics of Public Services, London: Macmillan, 1977, 174-205.

James Fries, "Aging, Natural Death and the Compression of Morbidity," New England Journal of Medicine, 303 (July 1980), 130-135.

Roger Gordon and Alan Blinder, "Market Wages, Reservation Wages and Retirement," Journal of Public Economics, 14 (October 1980), 277-308.

Daniel S. Hamermesh, "Social Insurance and Consumption: An Empirical Inquiry," American Economic Review, 72 (March 1982) forthcoming.

I.J. Irvine, "The Use of Cross-Section Microdata in Life-Cycle Models," Quarterly Journal of Economics, 96 (May 1981), 301-316.

Rodney Jacobs and Robert Jones, "Price Expectations in the United States, 1947-75," American Economic Review, 70 (June 1980), 269-277.

Lissy Jarvik et al, "Survival Trends in a Senescent Twin Population," American Journal of Human Genetics, 12 (1960), 170-179.

Lars Jonung, "Perceived and Expected Rates of Inflation in Sweden," American Economic Review, 71 (December 1980), 961-68.

Nathan Keyfitz, Applied Mathematical Demography, New York: Wiley, 1977.

Laurence Kotlikoff and Lawrence Summers, "The Adequacy of Savings," NBER Working Paper No. 627, February 1981.

David Levhari and Leonard Mirman, "Savings and Consumption with an Uncertain Horizon," Journal of Political Economy, 85 (April 1977), 265-281.

Jacob Mincer, Schooling, Experience and Earnings, New York: NBER, 1974.

Alicia Munnell, The Future of Social Security, Washington: Brookings, 1977.

Ralph Paffenberger and Robert Hyde, "Exercise as Protection Against Heart Attack," New England Journal of Medicine, 302 (May 1980), 1026-1027.

Samuel Preston, "The Age Incidence of Death from Smoking," Journal of the American Statistical Association, (1970), 1125-1130.

Charles Rose and Benjamin Bell, Predicting Longevity, Lexington, MA: D.C. Heath, 1971.

Sherwin Rosen and Paul Taubman, "Changes in the Impact of Education and Income on Mortality in the U.S.," in Social Security Administration, Office of Research and Statistics, Statistical Uses of Administrative Records, Washington: Government Printing Office, 1979.

Keith Sehnert, How To Be Your Own Doctor--Sometimes, New York: Grosset and Dunlap, 1975.

Jonathan Skinner, "Empirical Estimates of the Cost and Incidence of the Interest Income Tax," Unpublished Paper, UCLA, 1981.

Stephen Turnovsky, "A Test of the Expectations Hypothesis Using Directly Observed Wage and Price Equations," Review of Economics and Statistics, 54 (December 1972), 47-54.

Amos Tversky and Daniel Kahneman, "Judgement under Uncertainty: Heuristics and Biases," Science, 185, 1124-1131.

Menahem Yaari, "Uncertain Lifetime, Life Insurance and the Theory of the Consumer," Review of Economic Studies, 32 (April 1965), 137-150.

APPENDIX

Questionnaire on Subjective Life Expectancy

Part One

Please answer the questions on this page before going to the next page. Please do not change the answers here once you have completed this page.

Your age at your last birthday: _______ years.

Your sex: M _______ F _______

How old do you expect you will live to be? _______ years.

What is your subjective probability of living to at least age 60? _______ percent.

What is your subjective probability of living to at least age 80? _______ percent.

Part Two

Please answer each question as accurately as <u>your</u> knowledge of the facts allows.

1. a. Was your father born in the U.S. or Canada? Yes _______ No _______

   b. Is he still alive? Yes _______ No _______

   c. If you answered "Yes" on b; how old is he? _______ years.

   d. If you answered "No" on b; how old was he when he died? _______ years.

2-6 -- These were identical to 1, except they asked about the respondent's mother and grandparents.

7. Do you smoke more than 5 cigarettes/day on average? Yes _______ No _______

8. Do you engage in vigorous exercise (tennis, running, swimming, etc.) more than once a week on average? Yes _______ No _______

9. Have you ever been diagnosed as having a medical condition that had a non-negligible probability of being fatal? Yes _______ No _______

FOOTNOTES

1. Wall Street Journal, October 25, 1979, p. 1.

2. The numbers are even more striking for nonwhites. For example, between 1939-41 and 1980 average years of life remaining at age 25 increased by 7.4 among nonwhite males; for females the analogous figure is 12.8 years. (See Vital Statistics of the United States, 1977 Volume II, Section 5, and unpublished data for 1980.)

3. A detailed description of the construction of life tables is provided in Keyfitz (1977).

4. Comparing data for males age 25, life expectancy was: 1) 70.8 years in 1960/62, 70.7 years in 1970/72, and 71.5 years in 1976/78 in West Germany; 2) 70.4 years in 1960-64, 71 years in 1970, and 71.9 years in 1978 in France; and 3) 70.8 years in 1960/62, 71.1 years in 1967/69, and 72 years in 1976/78 in England and Wales. For females the comparable figures are: 1) 75.3, 76.1 and 77.4 in West Germany; 2) 76.6, 77.8 and 79.3 in France, and 3) 76.1, 76.8 and 78.6 in England and Wales. (See Statistisches Bundesamt, Statistisches Jahrbuch für die Bundesrepublik Deutschland, 1980; INSEE, Annuaire Statistique de la France, 1980; and United Kingdom, Statistical Office, Annual Abstract of Statistics, 1981. There is nothing inevitable about these increases; age-specific death rates rose in the Soviet Union between 1960 and 1975 for all adult age groups (U.S. Census Bureau, International Population Reports, Series P-95, No. 74, September 1980).

5. Robert Goldfarb and Ernst Stromsdorfer provided helpful advice in the construction of the questionnaire.

6. The age distribution of the respondents was: 26-29, N=29; 30-34, N=76; 35-39, N=75; 40-44, N=68; 45-49, N=60; 50-54, N=34; 55-59, N=40; and 60-65, N=29.

7. The age distribution of these respondents was: 20-24, N=22; 25-29, N=50; 30-34, N=64; 35-39, N=43; 40-44, N=28; 45-49, N=24; 50-54, N=43; 55-59, N=31; 60-64, N=29; 65-70, N=29. The questionnaire was the same as that sent to economists except that survival probabilities were elicited with questions styled as "how many chances in ten....?"

8. Where possible in this Section I use notation that has become standard among demographers. Thus, for example, what I denote later as p^{o}_{60} is the ratio of l_{60} to l_x from the life tables for white males in 1979.

9. Data on mortality by occupation are collected only infrequently, but they support this view clearly. In 1950 in the United States, age specific mortality rates of male college professors in ten-year age groups between 25 and 64 were roughly half those of all males, and only about 2/3 of those of all professionals. (U.S. Public Health Service, Vital Statistics Special Report, Volume 53, No. 2, p. 82.) In England and Wales in 1959-63 the figures for males in age groups between 25 and 64 present essentially this same pattern. (HMSO, Decennial Supplement to the

Registrar General's Report, 1961, Occupational Mortality Tables, p. 97, 99, 192.) Rosen and Taubman (1979) present results on a recent sample of older men showing much lower mortality rates among those with more education.

10. The conclusion that subjective expectancies correspond closely to actuarial is further strengthened by the sparse evidence from the 63 white females ages 20-70 who responded to the random survey. For them $\overline{x + e_x^s} = 79.40$, within two standard errors of the $\overline{x + e_x^o} = 80.97$, and significantly above the $\overline{x + e_x^s}$ reported by the white males in the sample.

11. The failure of the respondents to extrapolate past improvements is matched by the apparent inability of leading demographers to predict the changes that have occurred. For example, in 1945 one expert's most optimistic forecast for 1975 was that e_0^o would be 71.4 for the entire population; it was in fact 72.6. The forecast was sufficiently optimistic for mortality up through age 68, but insufficiently optimistic for mortality thereafter. (Dublin et al, 1949, pp. 172-174.)

12. That exercise increases longevity is suggested strongly by the studies discussed in Paffenberger and Hyde (1980).

13. A number of possible problems in the expanded version of (4) were examined. 1) There may be a simultaneity between e_x^s and smoking. While I cannot disprove this, in logit equations relating smoking to x and to all the dummy variables for parents' and grandparents' longevity, none of the latter set had a coefficient significantly different from zero. Similar logit equations for exercise yielded similarly insignificant results. 2) I specified Z so that the response to the longevity of male and female forebears is the same. When this restriction is relaxed, there is a lesser response to the experience of grandfathers than that of grandmothers; there is, though, a greater response to father's experience than to mother's. In any case the restriction that the responses be equal cannot be rejected statistically. 3) Finally, none of the conclusions changes when e_x^s and e_x^o are substituted for $x + e_x^s$ and $x + e_x^o$ in (4).

14. Elandt-Johnson and Johnson (1980) discuss the application of this distribution by demographers to characterizing survival probabilities implicit in life tables.

15. The other observations were dropped because the mean implied by the $\hat{c}_i$ and $\hat{\theta}_i$ exceeded 100 years. This occurred for persons whose subjective survival probabilities to ages 60 and 80 differed only slightly, resulting in absurdly high implied survival probabilities beyond age 90. In those cases the Weibull clearly does not describe the subjective survival distributions very well.

16. Maintenance of consumption has only recently been dealt with analytically as the main goal of social insurance programs by economists interested in these programs. See Hamermesh (1982) on unemployment insurance, and Kotlikoff and Summers (1981) on retirement benefits.

17. The function in (5) is suggested by that used by Gordon and Blinder (1980).

18. P_3 (t,τ) is calculated for $\tau-t\leq e^o_t$ by reducing $P_2(t,\tau)$ by twenty percent of a weighted sum of $(1-P_2(t,\tau))$ and $(P_2(t,\tau)-P_2(t,\ t+e^o_t))$, with weights based on the fraction $(\tau-t)/e^o_t$. For $\tau-t>e^o_t$ the probabilities P_3 are increased by the proportion required to equate life expectancy under P_2 and P_3.

19. For P_1 through P_4 I assume T = 81, i.e., maximum attainable age is 100. Under each scheme the probabilities of survival beyond age 85 are derived by prorating l_{85} for the particular year by the ratio l_x/l_{85}, $x>85$, for 1970. Interpolations of l_x within five-year age intervals were made for $20 \leq x \leq 85$, as were linear interpolations between 1930 and 1940, 1940 and 1950, etc., through 1970 and 1979. Finally, under P_2 through P_4 forecasts were assumed to be based on the life table for 1979.

20. The life-cycle earnings function is Mincer's (1974, p. 92), for annual earnings of nonfarm white males in 1959:

$$\ell n\ Y = +.068X - .0009X^2 + g(Z)\ ,$$

where Y are earnings, X is experience, and g(Z) is a vector of other variables (schooling and weeks worked). I set X=4 at age 20 (t=1) in the simulations.

21. I assume initial wealth is zero and ignore any bequest motive; its inclusion would make the simulation, which already requires the repeated construction of an optimal dynamic program, too costly to be practical.