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Can People Compute? An Experimental Test of the Life-Cycle Consumption Model

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I. Introduction

The assumption of rational choice is a cornerstone of modern economic theory. Rational choice requires that individuals correctly value their present and future resources, that they make consistent decisions, and that they obey the axiom of revealed preference. This chapter presents the results of an experimental study of consumption in which subjects were asked to make consumption decisions under hypothetical economic conditions. The questions in the experiment are designed to test the assumption of rational choice and to elicit information about preferences. The subjects' responses suggest a widespread inability to make coherent and consistent consumption decisions. Errors in consumption decision-making appear to be substantial and, in many cases, systematic. In addition, the experiment's data strongly reject the standard life-cycle model of consumption choice.

The principal specific findings of the laboratory experiment are as follows: (a) Subjects displayed significant inconsistencies in their consumption decisions; each of the subjects, in at least two pairs of economically identical situations, chose consumption values that differed by 20 percent or more. From the perspective of the standard life-cycle model, error in decision-making accounts, on average, for roughly half of the variation in individual consumption choices. (b) A sizeable fraction of subjects valued discounted future earnings less than present assets. (c) Almost all subjects exhibited oversaving behavior, apparently because they underestimated the power of compound interest. (d) The hypotheses that intertemporal consumption preferences are either homothetic or uniform across individuals are strongly rejected. (e) Consumption choice is only weakly correlated with subjects' stated intertemporal preferences.

In recent years an increasing body of research in experimental economics has sought to test many of the basic axioms of economic theory. Important experimental studies of rational decision-making include those of Allais and Hagen (1979), Grether and Plott (1979), Kahneman and Tversky (1979), and Tversky and Kahneman (1974). Laboratory exeriments have been used to study market and non-market institutions including competitive markets (Smith 1967), oligopolistic price setting (Plott 1982), public goods mechanisms (Smith 1982), auctions (Cox, Smith, and Walker 1985), and bargaining and negotiation procedures (Samuelson and Bazerman 1985). To our knowledge, however, this is the first experiment of consumption behavior.

Our laboratory experiment tests directly the life-cycle model of saving (Modigliani and Brumberg 1954; Ando and Modigliani 1963). A large body of theoretical and empirical research is based on the life-cycle model. Its influence on research and macroeconomic policy notwithstanding, tests of the life-cycle model with field data have proven inconclusive for reasons of data quality, inability to identify the consumer unit, incomplete knowledge of the consumer unit's information set, and lack of information about financial and other constraints confronting the consumer. It has proved particularly difficult to test directly the model's most basic assumption of intertemporal optimization by consumers. Recourse to experimental testing is, therefore, attractive because it alleviates a host of data and information problems.

The experiment was implemented by an interactive computer program in which subjects key in consumption choices in response to a series of questions. Forty-nine subjects (MBA students and undergraduates at Boston University) were paid to participate in the life-cycle simulation. Subjects were asked what consumption choices they would make if they were single, faced no uncertainty, had specified levels of future earnings and current assets, knew their ages of retirement and death, and could borrow and save at a specified interest rate.

The experiment presents subjects with two kinds of decision tasks. In parts I, II, and VI of the experiment, subjects are asked to make consumption and savings decisions year by year over their life cycle (from age 35 until death at age 75). In the other parts of the experiment, subjects made single year consumption choices under varying economic conditions (asset levels, earnings, interest rates). With the

experiment's data one can examine whether subjects tend to over- or undersave, whether subjects make identical consumption choices in economically equivalent (but different) situations, whether preferences are homothetic, and whether the present value of labor earnings and current assets, which together constitute the present value of resources, have an equal impact on consumption spending.

As experimental economists (see Vernon Smith, 1982) have forcefully argued, in certain respects experimental data permit more effective tests of theoretical models than does field data. The advantages of experimental analysis are those of control and measurement: the experimenter can control perfectly the exogenous economic environment and can measure all relevant economic variables without error. Since field data is subject to measurement errors and lack of controls, it may be difficult or impossible to determine from non-experimental data whether changes in behavior are due to differences in preferences or economic circumstances as opposed to nonoptimizing behavior.

The countervailing criticism of the experimental approach, of course, is that individual behavior in laboratory experiments may differ from real world decision-making. Vernon Smith (1982) uses the term "parallelism" to denote the extent to which the laboratory setting mimics the real world. In our view, the parallelism issue in our experimental setting is a matter of degree. Certainly our experimental setting is far simpler than the real world setting. However, parallelism need not be diminished (indeed, it may be enhanced) by simplification as long as the main factors affecting behavior in actual practice are captured in the design of the experiment. Though simplified, the description of the life-cycle setting contained in the experiment certainly resembles the kind of consumption and saving choices faced by individuals in their own lives.

Granted that the settings are parallel, it is obvious that both the analytical resources available to the individual and his decision-making incentives may differ between the experiment and the real world. In making real-world consumption and saving choices, individuals have more time and incentive to consider their decisions and to revise them. They also have the option to avail themselves of expert advice and observe the behavior of their friends and relatives. On the other hand, real world intertemporal optimization problems are far more complex than those presented in our experiment. They involve a variety of uncertainties and financial constraints, problems

of joint utility maximization in the case of families, and significant problems of information updating. Furthermore, our own casual empiricism suggests that individuals do not freely discuss their saving decisions, that the number who consult accountants and other professionals on these matters is relatively small, and that many individuals make their decisions without significant analysis. Thus, in providing responses to the experiment's questions, subjects may be acting quite similarly to the way they would act if actually faced with the comparable situation in the real world. Hence, experimental analysis may shed considerable light on actual consumption and saving decisions.

Section II provides a summary and review of the testable implications of the life-cycle model of consumption under certainty. Section III describes the design of the experiment and the subject population, and section IV presents the main results. Section V presents consumption choices and demographic characteristics. Section VI summarizes the findings and indicates our plans for additional experimental research on consumption.

II. Testable Implications of the Life Cycle Model Under Certainty

The life-cycle model under certainty posits that an individual chooses his consumption spending over his lifetime to maximize a concave utility function:

$$U = U(C_1, \ldots, C_d) \quad \text{subject to} \tag{1}$$

$$\sum_{j=1}^{d} C_j \prod_{s=2}^{j} R_s = A_1/R_1 + H_1, \tag{2}$$

where C_j is consumption at age j; d is the age of death; $R_s = 1/(1 + r_s)$, where r_s is the interest rate at time s; A_1 is initial assets; and H_1 is the present value of labor earnings (human wealth) as of age 1.

The fundamental presumption of this intertemporal optimization problem is that the individual's lifetime consumption and savings decisions are made without error. Thus, in an experimental setting that imposes constraint (2), a subject should make consumption decisions in precise accordance with life-cycle predictions. Two implications, stated as hypotheses, follow immediately from the general model.

HYPOTHESIS I: The individual should exhaust his resources at the time of his death (there are no leftover assets).

HYPOTHESIS II: An individual's consumption choice in a given year depends directly on the present value of resources and is independent of the mix of assets and the present value of lifetime labor earnings.

In addition, if consumption at each age is a normal good, we have

HYPOTHESIS III: An increase in the present value of resources leads to increases in consumption at each age.

If the utility function is homothetic and time separable, utility can be written as

$$U = v(C_1) + \beta v(C_2) + \cdots + \beta^{d-1} v(C_d), \tag{3}$$

where $\beta = 1/(1 + \delta)$, and δ is the individual's time preference rate. In this case, the individual's optimal consumption expenditure at age j can be expressed as:

$$C_j = PVR_j / \left[\sum_{s=j}^{d} \prod_{i=j+1}^{s} R_i h(R_i/\beta) \right], \tag{4}$$

where PVR_j is the present value of resources at age j, and where the function $h^{-1}(\,)$ is the marginal rate of substitution between consumption at different dates, that is,

$$C_{s+1}/C_s = h(R_{s+1}/\beta) \tag{5}$$

From (4) and (5) one sees that the assumption of separable utility implies the following strengthening of hypothesis III:

HYPOTHESIS IIIB: With the time path of the interest rate held constant, consumption in a given year is proportional to the present value of resources as of that date. Equivalently, the average and marginal propensities to consume are equal and independent of the level of PVR_j.

HYPOTHESIS IIIC: If the interest rate is constant, an individual's average and marginal propensities to consume are increasing functions of age.

Hypothesis IIIC holds because the right-hand-side divisor in (4) is smaller the larger is the initial age j at which the summation begins.

tions, while not precisely the same, presented the subjects with the same present value of resources (assets plus the present value of future earnings) at the same age, but differed in the relative contribution of assets and earnings to total resources. In addition, several pairs had the same level of assets and present value of labor earnings, but differed with respect to the lifetime profile of earnings.

Subjects were asked to make nine consumption decisions at age 35, three pairs of which had the same present value of resources. For age 46, there were thirteen decisions, including four pairs with the same present value of resources. For age 55, there were nine decisions, including four pairs with the same resources; and for age 69, there were seven decisions, including one pair with the same resources.

Listed below is a brief summary of the eight parts of the consumption experiment.

Part I—Annual Consumption Choices without Feedback

In this section the subject is asked to choose the level of annual consumption spending for each year from age 35 to age 74, inclusive (40 choices in all). The subject is allowed to modify his consumption choices until he is satisfied with them, but throughout, he receives no information about his accumulated balance in his savings account.

Part II—Annual Consumption Choices with Savings Feedback

Again, the subject reports his annual consumption expenditure for each year from age 35 to age 74, inclusive. In contrast to part I, however, the subject is informed of the accumulated balance in his savings account at the time he must make his next year's consumption choice. Consumption choices are made in chronological order—that is, the subject is not permitted to change an earlier consumption choice.

Part III—Consumption with Specified Assets at Selected Ages

Here the subject is presented with sixteen age/asset pairs and is asked to choose the level of consumption spending at that age given the specified balance in his savings account. The following are the age/asset pairs.

	Age			
	35	46	55	69
	Assets			
A.	43500	43500	43500	43500
B.	214000	214000	214000	214000
C.	130000	130000	130000	130000
D.	*	*	*	*

*Assets in D were set equal to accumulated assets at the same age in part II.

Part IV—Consumption with Different Retirement Ages

This section varies the retirement age and assets. The subject is asked to choose his consumption spending at age 46 assuming the following retirement ages and asset levels.

	Assets	Retirement Age
A.	500000	72
B.	100000	56
C.	100000	61
D.	100000	68

Part V—Consumption with Different Lifetime Earnings

In this part subjects are presented with ten different earnings profile/asset/age combinations and asked to choose consumption expenditure in each case.

		Age			
		35	46	55	69
	Earnings Profile*	Assets			
A.	23200/47800/32500	65000	65000	65000	
B.	33000/33000/33000	65000	465000	65000	
C.	20700/31000/42500	65000	65000	65000	65000

*The three numbers are the annual earnings in the three decades of work: ages 35–44, 45–54, and 55–64, respectively.

Table 10.1
Summary of lifetime consumption behavior

Age	Average	Coefficient of variation	25th percentile	75th percentile	Minimum	Maximum
35	17663	.248	15000	20000	9600	25000
36	17891	.223	15000	20000	10000	24000
37	18258	.198	15000	20000	10000	23000
38	18705	.187	16000	21000	10000	24500
39	18568	.192	15000	20000	10000	25000
40	19523	.214	17000	21000	10000	35600
41	19747	.155	18000	21000	14000	30000
42	19522	.171	18000	21000	12000	30000
43	19577	.196	17500	21963	8000	30000
44	19605	.169	18000	21963	10000	29000
45	19965	.141	19000	22000	15000	25000
46	20514	.233	18000	22000	15000	45000
47	19701	.160	18000	22000	10000	25000
48	20107	.171	18000	22000	10000	30000
49	20352	.238	18000	22000	15000	40000
50	21393	.217	18800	23000	15000	40000
51	21069	.265	18000	22000	11000	45000
52	20754	.217	19000	22000	15000	40000
53	20522	.186	19000	22000	14000	30000
54	20595	.188	19000	22000	15000	33000
55	20638	.172	19000	22000	15000	30000
56	21456	.163	19000	24000	15000	30000
57	21438	.193	19000	24000	12000	34000
58	21687	.261	19000	24000	13500	50000
59	21732	.260	20000	23000	13000	50000
60	22213	.287	19000	24000	14500	50000
61	22114	.267	20000	24000	15000	50000
62	22438	.299	19000	25000	10000	50000
63	22669	.350	19000	25000	10000	60000
64	24004	.491	19000	25000	10000	90000
65	27679	.343	20000	35000	9000	50000
66	27852	.295	22000	33000	10000	50000
67	30335	.366	22000	35000	17495	80000
68	31203	.341	23000	40000	8500	58000
69	34471	.461	24000	40000	10000	100000
70	36742	.419	25000	45000	8000	70000
71	37276	.477	25000	45000	8000	100000
72	37605	.503	25000	42000	4000	100000
73	35666	.449	23000	45000	4000	75000
74	55556	1.063	25631	64100	3000	311991

and maximum responses, and the levels of consumption at the 25th and 75th percentiles of the consumption distribution.

The average consumption expenditure rises throughout the course of the life cycle. Average consumption spending first exceeds $25,000, the amount of annual earnings, in the first year of retirement. The growth of average consumption is slow prior to retirement and very substantial after retirement; the ratio of average consumption at age 44 to that at age 35 is 1.11. In contrast, the age 74 to age 65 ratio is 2.01. This end-of-life rapid growth of consumption appears to be the result of oversaving. Although their asset balance is updated year by year, subjects do not appear to appreciate fully the amount of assets they are accumulating. Thus, in the last years of their life, they play "catch up."

There are sizable differences in saving behavior across subjects. The coefficient of variation averages nearly 20 percent from age 35 to 57 and increases steadily and substantially thereafter. Another measure of dispersion is the ratio of the 75th percentile consumption choice to the 25th percentile consumption choice. This ratio is 1.33 at age 35, 1.16 at age 45, 1.16 at age 55, 1.75 at age 65, and 2.50 at age 74. A third measure is the ratio of the maximum to the minimum consumption choice. This ration is 2.60 at age 35, 1.67 at age 45, 2.00 at age 55, 5.56 at age 65, and 104.00 at age 74. This increase with age in the dispersion of the consumption distribution suggests that not all subjects oversaved; some may have undersaved and those that oversaved may have oversaved in different degrees.

Table 10.2 presents summary data on subject consumption choices for the representative ages 35, 46, 55, and 69 as reported in parts III–V of the experiment. Recall that in these parts of the experiment each subject is asked for consumption choices at particular ages given an exogenously specified level of assets, a time path of future earnings, and a retirement age. The interest rate is 4 percent throughout these parts of the experiment. The table lists average average propensity to consume (APCs) and (MPCs) as well as key percentiles of the APC and MPC distributions at the four ages. Table 10.2 also indicates APCs for benchmark cases corresponding to lifetime consumption paths with −2 percent, 0 percent, 2 percent, and 4 percent constant yearly growth.

As predicted by the life-cycle model, the average APCs increase with age (hypothesis iiic). The dispersion of APCs, measured by the ratio of the 75th to the 25th percentile, is largest at age 69, where it is

Table 10.2
APCs and MPCs by age

	Age							
	35		46		55		69	
	APC	MPC	APC	MPC	APC	MPC	APC	MPC
Mean	.042	.049	.052	.048	.069	.072	.202	.187
Median	.041	.038	.049	.044	.064	.052	.185	.155
25th percentile	.036	.025	.045	.021	.058	.019	.166	.108
75th percentile	.045	.060	.054	.064	.071	.115	.227	.209
Benchmark profiles								
2% decline	.064	.064	.070	.070	.083	.083	.192	.192
Constant	.049	.049	.057	.057	.071	.071	.183	.183
2% increase	.036	.036	.045	.045	.060	.060	.175	.175
4% increase	.025	.025	.034	.034	.050	.050	.167	.167

1.37. This is somewhat surprising; one might expect less difficulty and more similarity in consumption choice after retirement because the present value of future labor earnings need not be computed.

The average MPCs are similar in magnitude to the average APCs, however, the dispersion of MPCs is much greater. The median MPCs are smaller than the median APCs at each age; at ages 55 and 69 the differences are sizeable.

Prior to age 69 the median APC falls between the constant and 2 percent increase benchmark APCs. At age 69, however, the median APC is slightly larger than that of the constant growth rate path.

The variation across subjects in APCs appears to be systematic. A total of 17 of the 49 subjects recorded APCs above the table 10.2 averages for all four ages; 14 other subjects exceeded the average in three of four cases. At the other extreme, 15 subjects recorded consumption below the average in three or more cases. In short, the population of subjects appears to be divided into two distinct groups of "big" and "small" savers.

Inconsistencies and Errors in Consumption Choice

Hypothesis II states that individuals should make the same consumption choice when facing the same present value of resources and the same interest rate. We tested this hypothesis by constructing in parts II–V 17 pairs of situations in which subjects faced identical

economic resources (at a 4 percent interest rate). Table 10.3 lists the percentage difference between each subject's chosen consumption expenditure for each economically equivalent (EE) situation. Percentage differences are computed in this table with the second minus the first case in the numerator and the first case in the denominator. To illustrate, the first column compares the subject's consumption choice in part II at age 35 to his later choice made at the same age and given the same economic circumstances in part III question *d*. The percentage errors of all subjects are listed in ascending order for each EE pair.

For all but three of the 17 EE cases in table 10.3, the average absolute error exceeds 20 percent. Clearly, this constitutes strong evidence of widespread consumption inconsistency and strongly contradicts hypothesis ii. Moreover, consumption errors are widespread across the subjects. As documented in table 10.4, each of the 49 subjects made at least two large consumption mistakes—an error in excess of 20 percent in absolute value. Thirty-seven of the 49 subjects made five or more large consumption errors in the 17 cases. Thirty-nine subjects made 1 or more very large errors—errors in excess of 40 percent in absolute value and, of these subjects, 11 made five or more very large errors.

A closer examination of table 10.3 and the summary information in table 10.3a indicates that many of the consumption errors are systematic. Consider, for example, the age 35 comparison of part III.C with part V.C. In III.C the asset level is $130,000, while it is $65,000 in V.C. Since total resources are equal in the two cases, the ratio of the present value of earnings to total resources is greater in V.C. In addition, the timing of labor earnings differs. In III.C the earnings path is a constant $25,000 until retirement. In V.C it is $20,700 from age 35 to age 44, $31,000 from age 45 to age 54, and $42,500 from age 55 to age 64. Taking III.C as the base, the median percentage change in consumption between III.C and V.C is negative 25 percent. Of the 30 subjects who answered these two questions (V.C was added after some initial experiments were conducted), only 3 had nonnegative errors (i.e., they increased their consumption from III.C to V.C). Some of the errors are quite sizable: 3 subjects reduced their consumption choice by more than 50 percent although they were in exactly the same economic choice situation.

The age-35 comparison of III.B with V.A also involves an increase in the earnings-resource ratio. Again, the median percentage error is

Table 10.3
Consumption errors

Age 35				
II–IIId	IIIc–Vc	Va–Vb	Vb–IIIb	IIIb–Va
−.500	−.625	−.250	−.250	−.800
−.500	−.622	−.250	−.242	−.770
−.200	−.513	−.250	−.219	−.763
−.150	−.400	−.250	−.219	−.714
−.080	−.400	−.077	−.207	−.700
−.042	−.375	−.000	−.200	−.667
−.006	−.370	.000	−.200	−.600
.000	−.333	.000	−.179	−.600
.000	−.320	.000	−.175	−.514
.000	−.280	.000	−.120	−.500
.000	−.250	.000	−.120	−.460
.000	−.240	.018	−.107	−.438
.000	−.240	.100	−.107	−.389
.000	−.227	.111	−.107	−.370
.000	−.217	.136	−.100	−.333
.000	−.214	.136	−.083	−.304
.000	−.200	.143	−.074	−.300
.000	−.200	.154	−.074	−.280
.000	−.200	.167	−.074	−.250
.000	−.189	.183	−.069	−.249
.000	−.167	.190	−.048	−.242
.000	−.150	.207	−.028	−.229
.000	−.138	.227	−.011	−.212
.000	−.133	.250	.000	−.200
.000	−.119	.250	.000	−.200
.000	−.100	.250	.000	−.200
.000	−.074	.259	.000	−.170
.000	.000	.273	.000	−.167
.000	.167	.280	.042	−.130
.000	.200	.316	.056	−.120
.000		.333	.100	−.120
.000		.333	.125	−.098
.000		.350	.167	−.080
.000		.350	.320	−.072
.000		.353	.333	−.072
.020		.391	.333	−.053
.029		.400	.471	−.050
.050		.422	.500	−.045

Table 10.3 (continued)

Age 35				
II–IIId	IIIc–Vc	Va–Vb	Vb–IIIb	IIIb–Va
.059		.462	.522	−.040
.067		.500	.600	−.007
.067		.500	.630	.000
.091		.500	.818	.000
.091		.579	.852	.000
.095		.600	1.000	.000
.105		.667	1.000	.040
.111		.739	1.500	.136
.133		.765	1.667	.143
.143		.813	2.333	.160
.200		.840	3.667	.667

Age 46					
II–IIId	IIIa–IVc	IIIc–IVd	IVa–Vb	IVa–IVb	IIIb–Vc
−.532	−.700	−.756	−.600	−.547	−.793
−.489	−.567	−.655	−.600	−.450	−.600
−.310	−.250	−.653	−.400	−.333	−.556
−.250	−.205	−.520	−.333	−.156	−.535
−.250	−.183	−.425	−.300	−.130	−.500
−.217	−.167	−.423	−.178	−.105	−.500
−.079	−.167	−.400	−.175	−.083	−.458
−.067	−.150	−.348	−.057	−.071	−.442
−.045	−.150	−.333	.000	.000	−.440
−.043	−.143	−.250	.000	.000	−.355
−.006	−.130	−.250	.000	.037	−.343
.000	−.100	−.222	.000	.080	−.333
.000	−.100	−.200	.000	.120	−.300
.000	−.091	−.200	.000	.143	−.243
.000	−.087	−.200	.000	.200	−.200
.000	−.053	−.191	.000	.250	−.200
.000	−.050	−.182	.086	.273	−.148
.000	−.050	−.167	.100	.450	−.133
.000	−.043	−.167	.111	.599	−.130
.000	−.024	−.143	.136		−.120
.000	.000	−.130	.167		−.120
.000	.000	−.100	.250		−.100
.000	.000	−.100	.277		−.100
.000	.000	−.091	.333		−.091
.000	.000	−.087	.500		−.065

Table 10.3 (continued)

Age 46					
II–IIId	IIIa–IVc	IIIc–IVd	IVa–Vb	IVa–IVb	IIIb–Vc
.022	.000	−.087	.500		−.033
.050	.000	−.083	.600		.000
.050	.000	−.080	.600		.000
.050	.000	−.056	.714		.000
.056	.016	−.042	.750		.000
.071	.029	−.021			.000
.100	.059	.000			.000
.100	.087	.000			.000
.111	.097	.000			.039
.125	.100	.000			.040
.130	.111	.006			.043
.150	.132	.042			.064
.156	.133	.043			.080
.167	.136	.050			.081
.176	.143	.053			.120
.211	.211	.057			.130
.222	.286	.058			.150
.222	.294	.095			.160
.250	.333	.100			.200
.353	.389	.200			.250
.375	.400	.200			.250
1.500	.469	.333			.350
1.900	.933	.333			.364
2.636	1.000	.750			.417

Age 55					Age 69
II–IIId	Va–IIIc	IIIc–Vb	Vb–Va	Vc–IIIb	I–IIId
−.480	−.400	−.750	−.375	−.612	−.450
−.130	−.385	−.583	−.333	−.423	−.350
−.120	−.354	−.483	−.231	−.400	−.333
−.120	−.321	−.333	−.200	−.383	−.193
−.111	−.320	−.267	−.200	−.375	−.167
−.091	−.308	−.222	−.200	−.375	−.143
−.091	−.280	−.200	−.185	−.371	−.143
−.087	−.276	−.167	−.167	−.353	−.126
−.041	−.259	−.167	−.130	−.333	−.113
−.019	−.250	−.167	−.120	−.286	−.100
−.006	−.250	−.167	−.107	−.286	−.091
.000	−.240	−.163	−.100	−.267	−.059

Table 10.3 (continued)

Age 55					Age 69
II–IIId	Va–IIIc	IIIc–Vb	Vb–Va	Vc–IIIb	I–IIId
.000	−.233	−.150	−.091	−.265	−.050
.000	−.200	−.128	−.091	−.263	−.050
.000	−.200	−.107	−.071	−.233	−.040
.000	−.200	−.091	−.063	−.233	−.008
.000	−.167	.000	−.050	−.233	.000
.000	−.158	.000	−.012	−.200	.000
.000	−.143	.000	.000	−.194	.000
.000	−.063	.000	.000	−.167	.000
.000	−.045	.000	.000	−.148	.000
.024	−.040	.000	.000	−.132	.000
.042	−.022	.042	.000	−.118	.029
.043	.000	.043	.000	−.100	.040
.045	.000	.050	.000	−.042	.042
.045	.000	.050	.000	−.040	.080
.050	.000	.059	.000	.000	.117
.053	.000	.105	.000	.000	.167
.068	.000	.111	.000	.000	.178
.105	.000	.136	.024	.000	.200
.136	.013	.136	.071	.000	.200
.167	.022	.150	.075	.000	.220
.179	.034	.167	.080	.029	.250
.222	.037	.167	.080	.030	.250
.263	.100	.182	.100	.087	.300
.316	.100	.190	.121	.103	.308
.333	.100	.211	.130	.143	.333
.364	.111	.227	.143	.231	.364
.364	.119	.250	.176	.250	.366
.412	.200	.250	.190	.278	.389
.438	.200	.278	.190	.280	.500
.500	.200	.333	.217	.346	.500
.667	.200	.375	.250	.361	.550
.733	.433	.381	.286	.372	.786
.750	.500	.381	.318	.724	.818
.818	.600	.400	.333	.875	1.000
1.857	.933	.667	.389	1.000	1.074
2.161	1.233	.750	.500	1.581	1.083
3.091	1.667	.957	.500	4.435	1.955

Table 10.3a
Summary information for table 10.3

	Average	Median	Absolute average	Type	d(Erns/Res)
Age 35					
II–IIId	−.004	.000	.056	1	.000
IIIc–Vc	−.231	−.250	.255	2	.112
Va–Vb	.255	.250	.298	3	.000
Vb–IIIb	.286	.000	.409	2	−.223
IIIb–Va	−.232	−.200	.279	2	.223
Age 46					
II–IIId	.141	.000	.234	1	.000
IIIa–IVc	.040	.000	.179	2	−.144
IIIc–IVd	−.107	−.087	.202	2	.066
IVa–Vb	.083	.080	.259	3	.038
IVa–IVb	.015	.037	.212	2	.068
IIIb–Vc	−.104	−.065	.216	2	.268
Age 55					
II–IIId	.264	.045	.317	1	.185
Va–IIIc	.034	.000	.243	2	−.009
IIIc–Vb	.059	.050	.228	2	.056
Vb–Va	.030	.000	.141	3	.026
Vc–IIIb	.088	−.042	.366	2	−.015
Age 69					
II–IIId	.198	.042	.296	1	.165

Type 1 = Identical circumstances.
Type 2 = Same resources, different earns/res.
Type 3 = Same resources, same earns/res, different earns pattern.

Table 10.4
The distribution of subjects by number of consistency mistakes and size of mistake

Percentage mistake	Number of subjects with specified number of mistakes										
	0	1	2	3	4	5	6	7	8	9	10+
20%+	0	0	3	3	6	6	11	5	6	3	6
40%+	10	13	5	5	5	3	2	3	0	1	2

negative; it is negative 20 percent. In this case, 10 of the 49 subjects reduced their consumption by 50 percent or more in switching from the III.B circumstances to the V.A circumstances. The age-35 V.B and III.B comparison is quite similar; here the earnings-to-resource ratio falls, and while the median error is zero, the mean is .29, with 12 of 49 errors in excess of positive 50 percent. Overall, in 8 of 10 type-two cases in which the earnings-to-resource ratio changes, the average error has the opposite sign of the change in the earnings-to-resource ratio.

In the age-35 comparison of V.A and V.B the earnings-to-resources ratio is unchanged. Compared with V.B, earnings in V.A occur earlier in the life cycle. Again, there seems to be an undervaluation of future earnings. In this case the median consumption error in switching to V.B is positive 25 percent, and 20 of 49 subjects increase their consumption by 30 percent or more.

Normality, Homotheticity, and Regression Tests of the Standard Life-Cycle Model

The standard life-cycle model assumes that preferences are homothetic and time separable, implying that consumption at a given age is proportional to the present value of resources (hypothesis iiib). Thus, the elasticity of consumption at each age, with respect to the present value of resources, should equal unity. To test the standard model we calculated income elasticities for each subject between each pair of consumption observations at specific ages. In this analysis we treated pairs of observations with identical resources as a single observation with the level of consumption equal to the average of the two choices.

For each subject there are ten income elasticities at age 35, 28 at age 46, 10 at age 55, and 15 at age 69. Table 10.5 indicates the distribution of elasticities for each age across all subjects, organized by the size of the elasticities. The fraction of elasticities that are negative are .30 at age 35, .25 at age 46, .43 at age 55, and .25 at age 69. These fractions are sizeable and raise serious doubt about the validity of the normality assumption. It is particularly surprising that normality is violated so frequently at age 69; at this age the subjects are retired and need consider only their assets. A number of subjects repeatedly violated normality. For example in their age-55 responses, 17 of the 49 subjects have negative income elasticities in a quarter or more of

Table 10.5
The distribution of income elasticities of the entire sample by the size of income elasticity

	Fraction of elasticities of size							
Age	<−1	−1 to −.5	−.5 to −0	0 to .5	.5 to .75	.75 to 1.25	1.25 to 1.5	1.5+
35	.13	.05	.12	.15	.04	.13	.04	.33
46	.11	.05	.09	.11	.08	.13	.06	.36
55	.22	.07	.14	.13	.06	.09	.04	.27
69	.10	.05	.10	.19	.12	.19	.05	.20

the possible cases; 7 of these 17 have negative income elasticities in half or more of the possible cases.

The negative income elasticities obviously contradict the homotheticity assumption. Moreover, the positive elasticities are also often far from unity. Indeed, at age 35 only 13 percent of the calculated elasticities fall between .75 and 1.25, and at age 46 it is also only 13 percent; it is only 9 percent at age 55; and it is only 19 percent at age 69.

Another test of the standard life-cycle model is provided by estimating a regression equation at each age of the form:

$$C = \alpha + \gamma R + u, \tag{7}$$

where R denotes the present value of lifetime resources, and u is an error term. Finding a significant regression intercept leads to a rejection of the homotheticity assumption. Separate regressions were estimated for each subject at each of the ages 35, 46, 55, and 69. The number of observations (i.e., resource and consumption pairs) for the regressions at these ages are 9, 13, 9, and 6, respectively.

The results of these regressions show that a significant minority of subjects displayed nonhomothetic consumption behavior. At age 35, the hypothesis of a zero intercept was rejected at the 5 percent significance level in 10 cases (of 49), at age 46 in 24 cases, at 55 in 4 cases, and at age 69 in 8 cases. The age-46 regressions contained the largest number of observations (16 compared to the next largest number 10). Of the 196 estimated constants (49 × 4), 36 intercepts were significantly positive while only 10 were significantly negative. Thus, for the bulk of nonproportional subjects, the predicted APC falls with income.

Table 10.6
Tests of the importance of the resource mix to consumption

	Number of regressions (fraction of regressions)				
Age	Total	$\sigma 1, \sigma 2$ Pos	$\sigma 1 > \sigma 2$	$\sigma 1, \sigma 2$ Signif Diff	$\sigma 1$ Signif $> \sigma 2$
35	49	35	36	14	14
46	49	44	24	11	6
55	49	45	17	16	5
Total	147	124	77	41	25

An additional test of homotheticity was conducted by including a quadratic term in the value of resources as an independent variable in the regressions. Of a total of 196 regressions, the coefficient on squared resources was significant (at the 5 percent level) in 24 cases. Thus, there appears to be evidence of some nonlinear consumption behavior.

Retaining the linear specification, a test that consumption is independent of the mix of resources (hypothesis ii) can be conducted by estimating regressions of the form

$$C = \alpha + \sigma_1 A + \sigma_2 E + u, \tag{8}$$

where A denotes the subject's accumulated savings to date, and E denotes the present value of his future earnings. Of course, the irrelevance of the mix of resources implies that σ_1 should equal σ_2. We estimated (8) separately for ages 35, 46, and 55 (at age 69 future earnings were zero). Table 10.6 presents a summary of the distribution of assets and earnings coefficients.

In 85 percent of the cases (124 of 147 regressions), the earnings and assets coefficients are both positive as predicted by the life-cycle model. The coefficient on assets exceeded that on earnings in slightly more than half of the 147 regressions. In total, 41 of 147 (or 28 percent) of the regressions displayed coefficients that are statistically different from one another at the 5 percent level. In these 41 cases, the coefficient on assets exceed that on earnings by 25 times. Finally, there is only a single, insignificant asset coefficient (which is negative), but 16 negative earnings coefficients, 8 of which are significant. From these results it appears that a significant minority of subjects undervalue earnings relative to assets, while a somewhat smaller

minority overvalue earnings. Table 10.6 summarizes these findings and presents the age-specific results.

Tables 10.7a–10.7d consider whether nonhomotheticity and the resource mix are significant in pooled regression analysis. The table displays the coefficients of four regression models estimated for the four key ages with the data pooled across all subjects. Model A explains consumption only in terms of total resources. Model B differs from A by the addition of an intercept. Model C modifies B by entering assets and earnings separately. Model D adds the squares of assets and earnings and the product of assets and earnings.

The model B intercepts in each of the four tables, 10.7a through 10.7d, are highly significant. Thus, these pooled regressions reject the homotheticity hypothesis. The model B coefficients on resources also contradict the life-cycle model's prediction that the marginal propensity to consume increases with age. Although all are insignificant, the coefficients at ages 35, 46, 55, and 69 display no strong positive correlation with age.

Given that an intercept belongs in the relation between consumption and resources, is it also the case that earnings and assets enter with the same coefficient? That is, do subjects value equally a dollar in assets and a dollar in human wealth? According to *F*-tests of model B vs. C, reported in table 10.8, the assumption of equal valuation of assets and earnings is strongly rejected for the pooled age-35 data, but accepted for the pooled age-46 and pooled age-55 data. In the age-35 model C regression, the assets coefficient is over seven times greater than the earnings coefficient. These results may reflect an inability of subjects to discount properly far distant earnings streams; that is, at ages 46 and 55 the future earnings streams extend for a shorter interval than at age 35.

The results on model G reinforce a view of undervaluation of future earnings. The APC is negatively related to the earnings-to-resources ratio at each of the three ages 35, 46, and 55. The earnings-to-resources coefficient is highly significant at ages 35 and 46. Hence, the larger the share of the present value of earnings in total resources, the smaller the average propensity to consume.

One may also question whether higher-order powers of assets and earnings help explain consumption. As indicated in table 10.8 (in the C vs. D *F*-test) these additional variables are jointly significant for the age-35 and the age-46 regressions. Table 10.8 also reports the results of a Chow test, assuming model B, indicating whether it is appro-

Table 10.7a
Age 35 pooled regression coefficients (standard errors)

Model	Res	Const	Earn	Assets	Earn*Assets	Squared Earn	Squared Assets	Earn/Res	$\bar{R}^2$
A	.042								.151
	(.001)								
B	.051	−4989							.156
	(.006)	(3461)							
C		11791	.012	.085					.249
		(4061)	(.008)	(.007)					
D		234167	−.851	−.431	.547	.821E−6	.683E−6		.263
		(88865)	(.340)	(1.101)	(1.173)	(.318E−6)	(.145E−5)		
(Dep Var is APC)								−.049	.088
G	.085								(.008)
	(.007)								

Table 10.7b
Age 46 pooled regression coefficients (standard errors)

Model	Res	Const	Earn	Assets	Earn*Assets	Squared Earn	Squared Assets	Earn/Res	$\bar{R}^2$
A	.049								.185
	(.001)								
B	.038	6625							.207
	(.004)	(2033)							
C		7234	.036	.039					.207
		(2681)	(.007)	(.005)					
D		2075	.026	.128	−.024	.242E−7	−.146E−7		.224
		(10363)	(.058)	(.175)	(.252)	(.677E−7)	(.136E−6)		
(Dep Var is APC)									
G	.052							−.100	.000
	(.006)							(.008)	

Table 10.7c
Age 55 pooled regression coefficients (standard errors)

Model	Res	Const	Earn	Assets	Earn*Assets	Squared Earn	Squared Assets	Earn/Res	$\bar{R}^2$
A	.007								.066
	(.002)								
B	.056	−4367							.069
	(.010)	(3833)							
C		1961	.068	.053					.072
		(4362)	(.014)	(.011)					
D		−15173	−.165	−.440	.398	−.136E−6	−.828E−6		.085
		(29221)	(.233)	(.646)	(.923)	(.366E−6)	(.103E−5)		
(Dep Var is APC)									
G	.061							−.012	.003
	(.008)							(.011)	

Table 10.7d
Age 69 pooled regression coefficients (standard errors)

Model	Res	Const	$\bar{R}^2$
A	.176		.40
	(.005)		
B	.034	8404	.15
	(.005)	(2575)	

Table 10.8
Significance values of *F* tests for pooled regressions

	Age			
Test	35	46	55	
B vs. C	.404E−7	.728	.249	
C vs. D	.024	.014	.075	
B Pooled vs. Unpooled	.955E−7	.111E−15	.001E−18	.115E−15

priate to pool the data. Pooling the data is very strongly rejected for each of the four ages; that is, there is very significant heterogeneity in individual model B regression coefficients.

A final way to evaluate the performance of the standard life-cycle model is in terms of *R*-bar square. If the model is correct, the *R*-bar squares in the regressions of consumption against resources (model A) should be unity. This is far from the case. Table 10.9 reports the distribution of *R*-bar squares from subject-specific regressions for several of the models of tables 10.7a–10.7d for each of the four reference ages. For a large percentage of subjects the standard time-separable homothetic model, model A, explains only a modest fraction of the total variance in consumption choice. For example, at age 46 one half of the *R*-bar squares are below .5; 30 percent fall below .25. The *R*-bar squares for models C and D are somewhat higher, but even for model D at least a third of the *R*-bar squares at each age are less than .75.

Evidence of Oversaving

Perhaps the most severe challenge to accurate choice is posed in the year-by-year consumption decisions of parts I and II. Recall that in part I, subjects make their year-by-year decisions without feedback

Table 10.9
Distribution of $\bar{R}^2$s from alternative regression models

			Fraction of $\bar{R}^2$s of size				
Model	Age	<0	0–.25	.25–.5	.5–.75	.75–.85	.90–1
A	35	.22	.18	.29	.20	.08	.02
	46	.20	.12	.18	.31	.14	.04
	55	.27	.16	.24	.24	.06	.02
	69	.14	.02	.06	.22	.10	.45
C	35	.20	.06	.22	.27	.14	.10
	46	.12	.08	.14	.37	.14	.14
	55	.12	.10	.12	.39	.10	.16
D	35	.22	.08	.08	.24	.04	.33
	46	.04	.06	.06	.33	.12	.39
	55	.10	.06	.14	.10	.16	.43

(i.e., without any information concerning the accumulated balance in their savings account). In part II, subjects received this feedback year-by-year. Clearly, the information provided in part II better conforms to the information available in "real world" consumption and saving decisions. Our objective in studying the nonfeedback settings was to gain insight into subjects' abilities to discount and also to compare consumption choices with and without asset feedback.

In part I the overwhelming majority of subjects left significant positive asset balances at the conclusion of their lives. While the average value of age-74 consumption chosen is $25,709, the average value of assets unspent at age 75 is an astounding $250,000. Overall, 36 of 46 subjects (three subjects' responses to part I were invalidated by key punch errors) left balances at age 75 in excess of $50,000; nearly two-thirds of the subjects left assets in excess of $200,000, and over one-third left assets in excess of $300,000.

Table 10.10 lists the amount of assets not spent by the end of life in part I in ascending order in the first column. The second column considers the subjects in the same order as the first column and indicates the level of consumption at age 74 chosen by the subjects in part I. The third column gives the ratio of the first to the second column. The fourth column expresses the present value of the amount of end-of-life unspent resources as a percent of the initial age-35 present value of resources. The average ratio of unspent end-of-life assets to age-74 consumption is 13.97, and the median ratio is 13.26.

Table 10.10
Part I Oversaving behavior

End-of-life assets	Age 74 consumption	Ratio of column 1 to column 2	Ratio of the present value of end-of-life assets to the present value of resources
−385233	100000	−3.85	−.178
−93992	50000	−1.88	−.044
−58329	24000	−2.43	−.027
−25614	40000	−.64	−.012
1	21000	.00	.000
6064	25000	.24	.003
9294	20000	.46	.004
17526	25000	.70	.008
35865	20000	1.79	.017
41740	100000	.42	.019
71726	15000	4.78	.033
98152	40000	2.45	.045
114038	15000	7.60	.053
126193	12000	10.52	.058
133541	16000	8.35	.062
181975	20000	9.10	.084
201976	15000	13.47	.094
209846	25000	8.39	.097
217359	20000	10.87	.101
243476	16000	15.22	.113
254577	15000	16.97	.118
257139	18000	14.29	.119
265955	22100	12.03	.123
280801	19000	14.78	.130
280844	25000	11.23	.130
293823	30000	9.79	.136
307669	18500	16.63	.143
308462	25000	12.34	.143
319849	22000	14.54	.148
333265	20000	16.66	.154
352145	26550	13.26	.163
354585	25000	14.18	.164
368681	25000	14.75	.171
378563	25000	15.14	.175
394742	17000	23.22	.183
401699	20000	20.08	.186
419154	18000	23.29	.194
439242	25000	17.57	.203

Table 10.10 (continued)

End-of-life assets	Age 74 consumption	Ratio of column 1 to column 2	Ratio of the present value of end-of-life assets to the present value of resources
443701	25000	17.75	.206
482401	24000	20.10	.223
527973	35000	15.08	.245
529761	30000	17.66	.245
566066	18000	31.45	.262
605157	10000	60.52	.280
676817	16000	42.30	.314
765124	10000	76.51	.354

In total, 28 of the 46 subjects who answered part I failed to spend 10 percent or more of their lifetime resources; 9 of the 46 failed to spend 20 percent or more of their lifetime resources; and 2 of the 46 failed to spend 30 percent or more.

Further suggestion of oversaving comes from comparing the age-consumption profiles of part I with those of part II. Figure 10.2 displays the two profiles of one of the subjects. Note that the part I profile is generally below the part II profile. In the initial working years the two profiles closely track one another. In later years, after observing a significant amount of accumulated assets in part II, the subject rapidly readjusts his consumption spending upward.

Though consumption behavior varies markedly across subjects, the general characteristics of figure 10.2 are quite similar for many subjects. For 36 of 48 subjects, part II consumption profiles exceed part I profiles for all but a small number of years. A quantitative measure of the relative consumption behavior with and without feedback is provided by comparing accumulated savings at a given age. At age 69, 44 of 48 subjects had significantly smaller asset balances in part II than in part I. In part II, the average level of age-69 assets was $250,000; in part I it was $350,000.

With the benefit of asset feedback in part II, subjects exhibited what might be termed "adaptive" consumption behavior. However, even in part II it is clear that subjects did not succeed in choosing optimal consumption profiles. Rather they appear to oversave in the early stages of their working lives and then to engage in rapid spending, especially during their last ten to fifteen years. To illustrate this point, we calculated for part II the number of years of age-64

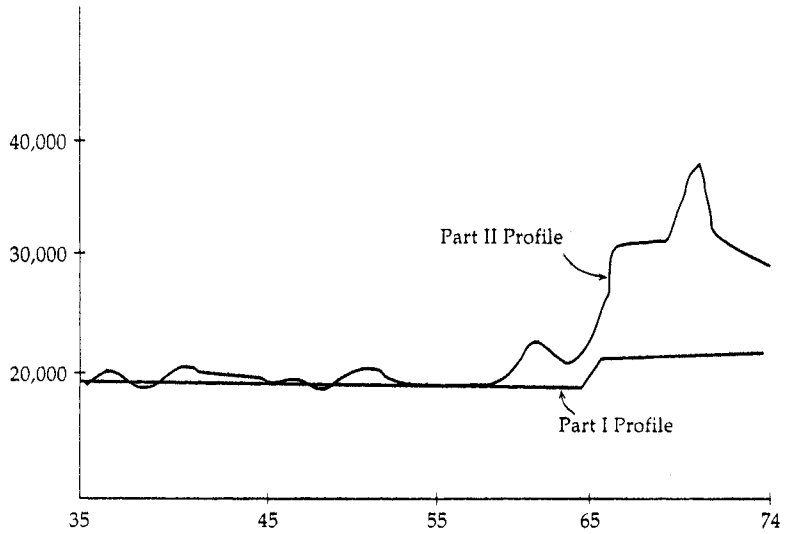

Figure 10.2
Comparison of part I and part II profiles

consumption that could be financed by the subject's age-65 assets. If the individual's aim was to have constant consumption over the last decade of life, then his age-65 assets would be sufficient only to finance ten years of the age-64 consumption level. In fact, for a significant minority of the subjects, age-65 assets are sufficient to finance their age-64 level of consumption for many more than ten years.

Table 10.11 presents the part II consumption choices of subjects in the last ten years of life. The table's first column lists in ascending order the level of assets at age 65; the second column presents the corresponding age-64 level of consumption; the third column presents the largest level of consumption over the remaining ten years, age 65 through 74. The forth column gives the number of years of consumption at the age-64 level that could be financed with age-65 assets.

A total of 29 of the 49 subjects had assets at age 65 that could finance ten or more years of their age-64 level of consumption; 9 had sufficient resources to finance twenty or more years of age-64 consumption; and 5 had enough assets at age 65 to finance thirty or more years of age-64 consumption. Those subjects who could finance twenty or more years of age-64 consumption realized at some point

in their remaining ten years of part II that they had sizeable amounts of assets, at which point they dramatically adjusted upward their consumption. A comparison of columns two and three of the table indicates that the high-savers (those for whom column five exceeds 20), for at least one of their remaining ten years, chose a consumption level that, on average, equaled 6.5 times their age-64 consumption.

Comparisons of Actual Consumption Choices with Expressed Preferences

Recall that in part VIII subjects were asked to rank in order of preference five feasible consumption profiles: a constant profile, profiles with 2 percent, 4 percent, and −2 percent annual growth, and a step function with $23,000 in annual consumption prior to retirement and $10,000 thereafter. A natural question is whether the life-cycle consumption paths chosen by subjects in part II are consistent with their preference rankings reported in part VIII. In principal, one would like to have precise information about each subject's utility function. But the difficulty in eliciting such information makes that approach impractical. Instead, we compare a given subject's actual consumption choice with his preference ranking of the part VIII alternatives.

Table 10.12 indicates the fraction of subjects listing each profile as their first or second ranked alternative. Three-quarters of all subjects listed the 2 percent growth path as their first or second choice. The constant path is next in popularity, followed by the 4 percent growth path. The great majority of subjects also displayed "single peaked" preferences, choosing as their second profile choice a profile close to their first choice.

It is interesting to compare the part II profiles chosen by subjects with their consumption profile rankings. A useful measure of the closeness of these choices is the average annual absolute percentage difference between the part II profile and the most preferred part VIII. For those whose first choice in VIII is a constant profile the mean percentage deviation is 15 percent; for those with first choice profiles of 2 percent, 4 percent, −2 percent, and the step function mean deviations are 21 percent, 25 percent, 37 percent, and 46 percent. These mean percentage differences are quite large.

A second comparison of consumption choice with part VIII expressed preferences is summarized in table 10.13. The second row of this table lists the number of subjects whose actual part II choices

Table 10.11
Part II Oversaving behavior

Age 65 assets	Age 64 cons.	Largest post-64 cons.	Years of age 64 consumption affordable from age 65 assets
35885	30000	20000	1
108895	90000	25000	1
109107	18000	32526	6
113478	20000	40000	6
114490	21963	21002	5
123102	22000	39546	6
126668	27500	39157	4
127440	22000	31199	6
140088	22000	30000	7
142006	40000	50000	3
145527	20000	31000	8
161457	28000	35000	6
171288	24000	40000	8
172429	30000	38000	6
173850	19000	70954	11
176054	25000	50000	8
176701	30000	45000	6
183500	18000	66199	12
192288	22000	60000	10
193384	15000	39529	17
194727	25000	50000	9
195945	18000	40000	13
197989	25000	50000	9
198271	20000	55830	12
203607	28000	45000	8
204173	24000	52615	10
205148	15900	56000	17
212663	20000	47000	13
213833	19000	127000	14
224233	41129	41130	6
233823	19000	55000	16
244782	25000	70000	12
256051	24000	70000	13
256887	30000	66925	10
260740	20000	51598	17
261302	28000	65754	11
267808	25000	90715	13
294322	20000	140000	21
296081	23000	60000	17

Table 10.11 (continued)

Age 65 assets	Age 64 cons.	Largest post-64 cons.	Years of age 64 consumption affordable from age 65 assets
300673	10000	70000	∞
307186	10000	91936	∞
319143	19700	143000	24
321064	28000	100000	14
328270	19000	80000	27
335706	15000	100000	50
337159	20000	100000	26
343607	25000	70000	19
395443	15000	255789	∞
406827	20000	50000	38

∞ Resources can finance a perpetuity.

Table 10.12
Ranking of alternative consumption profiles

	Fraction of subjects choosing alternative profiles				
	0%	2%	4%	−2%	Step
First choice	.23	.31	.25	.13	.08
Second choice	.23	.44	.15	.11	.17

Table 10.13
Correlation of part II choices with part VIII ranking

	Profiles				
	0%	2%	4%	−2%	Step
# of subjects	11	15	12	6	4
Closest	5	10	4	0	0
2nd Closest	4	5	3	0	0
3rd Closest	0	0	0	4	3
4th Closest	0	0	0	0	1
5th Closest	2	0	5	2	0

came closest in terms of mean percentage error to their top ranked choice in VIII. The third row lists the number of subjects whose consumption choice more closely resembles their second ranked profile in VIII, and so on. It is clear that many subjects failed to choose profiles that came closest to their ranking in VIII; only 19 of 48 subjects chose in II a profile that came closest to their most preferred in VIII.

Estimates of Time Preference Rates and Intertemporal Elasticities of Substitution

The time preference rate and the intertemporal elasticity of substitution are key parameters in standard analyses of the supply of savings and the efficiency gains from tax reform (see, for example, Summers, 1981 and Auerbach and Kotlikoff, 1987). Estimates as large as 18 percent for the rate of time preference have been reported by Hausman (1979), but most estimates appear to center around 1.5 percent (Lawrence 1985). In the case of the intertemporal elasticity of substitution, the majority of estimates range from 0.2 to 0.5 (Auerbach, Kotlikoff, and Skinner 1983). These parameters have often been estimated assuming homothetic, time-separable preferences. While our data reject such preferences, it is still useful to determine whether estimates of these parameters based on experimental data are in accord with those based on actual data. If they were substantially different one would presumably be more skeptical of the quality of these experimental data.

We can calculate these preference parameters using the data from part VII which asked subjects to choose a time path of consumption in the presence of time-varying interest rates. Estimation of (5′) based on the pooled data yields an estimate of .376 for the intertemporal elasticity of substitution and .018 for the time preference rate. The standard error of the elasticity of substitution is .578; given the estimate of the elasticity of substitution, a standard error in the intercept of (5′) implies values of the time preference rate ranging from −.042 to .081.

The individual estimates of (5′) are, however, significantly different from the pooled estimates. The *F*-test, determining whether individual coefficients in the regression of equation (5′) equal the pooled coefficients, is significant at the .003 percent level.

Estimating (5′) separately for each subject yields only three significant estimates of the intertemporal substitution elasticity. A total of

Table 10.14
Regressions of APCs on demographic characteristics

	Coefficients (standard errors)			
	Age 35	Age 46	Age 55	Age 69
Constant	.324E−1	.735E−1	.843E−1	.308
	(.632E−2)	(.828E−2)	(.113E−1)	(.447E−1)
Male	.448E−2	.304E−2	.152E−1	.182E−1
	(.215E−2)	(.275E−2)	(.383E−2)	(.152E−1)
Age	.913E−3	−.210E−3	.241E−3	−.266E−2
	(.294E−3)	(.424E−3)	(.524E−3)	(.298E−2)
Yrs Col	−.358E−2	−.372E−2	−.743E−2	−.123E−1
	(.800E−3)	(.144E−2)	(.143E−2)	(.566E−2)
Italian	−.109E−1	−.148E−1	−.181E−2	−.346E−1
	(.433E−2)	(.655E−2)	(.772E−2)	(.306E−1)
Jewish	.746E−2	.541E−2	.251E−1	.466E−2
	(.337E−2)	(.440E−2)	(.602E−2)	(.239E−1)
Catholic	−.438E−3	−.753E−2	.504E−2	−.282E−1
	(.268E−2)	(.379E−2)	(.478E−2)	(.189E−1)
Asian	−.908E−3	−.142E−1	−.118E−3	−.663E−1
	(.281E−2)	(.355E−2)	(.502E−2)	(.199E−1)
Hispanic	.380E−2	−.424E−2	−.438E−3	.620E−2
	(.312E−2)	(.366E−2)	(.556E−2)	(.220E−1)
Black, Ot.	−.613E−2	−.104E−1	−.569E−2	−.487E−1
	(.322E−2)	(.524E−2)	(.574E−2)	(.227E−1)
Poor parents	.941E−2	.159E−1	.138E−1	.762E−1
	(.424E−2)	(.617E−2)	(.756E−2)	(.300E−1)
Rich parents	−.982E−2	−.119E−1	−.238E−1	−.536E−1
	(.201E−2)	(.271E−2)	(.358E−2)	(.142E−1)
Exp to be Rich	−.635E−3	.486E−2	−.556E−2	.210E−1
	(.202E−2)	(.304E−2)	(.360E−2)	(.143E−1)

24 of 49 substitution elasticities are negative; of the remaining 25 elasticities only 3 are less than 0.5; 15 exceed 1. Of the 49 estimates of the rate of time preference, 4 are negative; 18 are between zero and .03; and 5 exceed .10.

V. Consumption Choices and Demographic Characteristics

One way to exhibit consumption choice differences by demographic groups is to regress APCs against characteristics. Table 10.14 reports the coefficients from such regressions for ages 35, 46, 55, and 69, where all the data in parts II through V which assume a 4 percent interest rate are pooled. The demographic variables include dummy

variables for males, Italian, Jewish, Catholic, Asian, Hispanic, Black and others. There are also dummies for the income position of the subject's parents. "poor parents" and "rich parents" are dummies for subjects with parents who they consider to be in lower income and upper income groups, respectively. "Exp to be Rich" is a dummy for subjects who expect to be in high-income groups later in life. The excluded group is female, white Protestants, with middle-income parents, who do not expect to be in the high-income group. In addition to these dummy variables, "Age" is the subject's age and "Yrs Col" is the subject's number of years of college.

The combined set of demographic variables are highly significant in all four regressions, thus adding further evidence about consumption heterogeneity. The specific results suggest that males consume significantly more than females, that Asians, Italians, and Blacks consume less than White Protestants, that Jews consume more than white Protestants, and that those with more years of college consume less than those with fewer years of college. The significant Asian dummies are not surprising, but the coefficients on the dummies for Italians, Blacks, and Jews are rather surprising.

The last three dummy variables in the regressions are also quite interesting. Subjects with poor parents consumed significantly more and those with rich parents significantly less than those with middle-income parents. One may speculate that rich parents have imbued their children with stronger saving ethics than poor parents. The insignificance of the "Exp to be Rich" dummy suggests that subjects were able to abstract from their own personal circumstances in responding to the experiment. If such abstraction were quite difficult, one would expect this coefficient to be significantly positive.

A second interesting question is which subjects are more likely to make consumption mistakes. A pooled regression of the absolute percentage errors from table 10.3 (but redefined with the smaller consumption value in the denominator) on the explanatory variables of table 10.14 produced significant positive male and Jewish coefficients, and a significantly positive coefficient on "Poor parents." In addition, the coefficient on "Yrs Col" was significantly negative.

VI. Summary and Conclusion

A variety of findings in our life-cycle consumption experiment raise serious questions about the life-cycle model's ability to describe consumption choice. In their life-cycle consumption choices, many subjects repeatedly made substantial errors; they chose quite different levels of consumption in identical economic situations, and they oversaved, typically by very sizeable amounts. These errors are often systematic and appear to reflect a widespread inability to discount properly future earnings streams. Many subjects clearly undervalue future earnings streams, while a smaller number overvalue future earnings. Given these errors, it is not surprising that the standard life-cycle model typically explains less than half the variance in consumption. In addition, the experiment's data significantly reject the hypotheses that intertemporal consumption preferences are either homothetic or uniform across individuals. Indeed, differences in preferences appear to be substantial and are correlated, in part, with demographic characteristics.

These findings have important policy implications. If large segments of the population undervalue future income streams, then policies, such as social security and tax cuts, will alter saving because they change the timing of income. Thus a fully funded, actuarially fair social security system that provides future benefits in exchange for current payroll taxes will depress consumption and increase saving if future benefits are undervalued. Alternatively, a cut in current income tax receipts coupled with an equal present value increase in future income tax receipts will stimulate consumption and lower saving.

The findings also suggest that Keynesian models, which place greater emphasis on current relative to future income streams, may better describe actual consumption choice. But the Keynesian model, while perhaps a better descriptive tool, is probably too naive, just as the life-cycle model appears to be too sophisticated. What is needed is a better model of choice in the context of bounded rationality.

We believe that experimental research on consumption choice can provide a set of empirical regularities that will instruct the development of models of bounded rationality. In addition, experiments incorporating policy variables may prove a useful tool in policy formulation and analysis. In our future experimental research we intend to explore the responses to policy variables. In addition, we hope to gain more insight into the nature of consumption mistakes by examining directly whether subjects can discount and by correlating mistakes in discounting with mistakes in consumption choices. A third area of future experimental research is consumption choice under uncertainty.

Appendix: Consumption, Study Instrument

Introduction

We are interested in learning how people make saving decisions. We are going to ask you how much you would choose to consume in the following hypothetical circumstances.

General Circumstances

You are age 35, unmarried, and about to start your first job. You will work on this job until you retire at age 65. Each year you must decide how much money to spend on consumption and how much money to save. When you retire, your salary will cease. After you retire you will live for ten more years and die at age 75.

Your Specific Circumstances

1. You are single and will never get married. You have no children, parents, or other relatives to care for. You are going to spend all of your money over your lifetime on your own consumption.

2. You face no uncertainty whatsoever about the future. You will live for certain until age 75. You will be in excellent health and never have to pay a cent for medical or dental care. You will work full-time until age 65 when you retire.

3. Any money you save is deposited in your savings account and earns 4 percent interest per year. You may borrow money at any time in which case you must pay 4 percent interest on your borrowings.

4. There is never any inflation or deflation in your economy; that is, prices never change.

5. There are no taxes in your economy.

6. All events in your life occur on January 1. You were born on January 1. You get paid—in advance—for the coming year's work on January 1. You will retire on January 1. You receive interest on savings or pay interest on borrowing on Jan. 1. In addition, you make all your consumption expenditures for the year on January 1. You will die on December 31st, 2026, the day before you turn 75.

7. Consumption expenditures include purchases of food and clothing, payment for vacations during the year, payment for utilities for the year, and rental of housing and durable goods.

8. You always rent housing by the year as well as all durable goods like cars, refrigerators, furniture, stoves, televisions, air conditioners, etc. On January 1 of each year you pay all of the rent for the coming year. There are no moving costs, hassle costs, or any other costs of your renting a bigger house or apartment or, for example, of renting a smaller car or bigger dishwasher.

Basic Fact Sheet

General

This questionnaire has eight parts and should take from one to one-and-a-half hours to complete. We recognize the experiment is somewhat lengthy but ask that you try to be as conscientious as possible throughout. Please take your time and try to answer every question thoughtfully, on the basis of what would make you most happy given the situation described to you. We suggest that after you complete part IV you take a five-minute break. At that time, please help yourself to the refreshments we have provided.

If you have any questions *whatsoever* during the experiment, please stop and speak to one of the proctors. We strongly discourage guessing when at all in doubt.

Summary of Your Facts of Life

1. You begin working at age 35 with no savings.

2. You retire at the end of your 64th year, so 64 is the last year you work and earn a salary. (The only exception to this is part IV, which varies the retirement age.)

3. You die, *with certainty*, at the end of your 74th year, so 74 is the last year in which you can consume.

4. With the exception of part V, you always earn a $25,000 salary each year until you retire.

5. The interest rate is always 4 percent (except in Parts VI and VII). Your savings account will earn interest at that rate; you may always borrow as much as you wish at that interest rate.

6. Interest Computation: Your assets on January 1 of any year are equal to 1.04 times the sum of your assets on January 1 of the previous year plus your earnings on January 1 of the previous year less your consumption on January 1 of the previous year. Thus, if assets

last January 1 were $10,000, earnings were $25,000, and consumption was $23,000, then assets this January 1 would equal 1.04 times ($10,000 + $25,000 − $23,000) = 1.04 × $12,000 = 12,480.

Operating the Computer

- In responding to any question, type *only* numerals, no commas, dollar signs, decimals, etc.
- With the exception of part I, part VII, and part VIII, entry of an answer requires two steps. First, you key the number you wish to enter and press the return key. Second, once you have looked at the number you have typed on the screen to make sure you've typed it correctly, type the ampersand (&—shift 7) to confirm the entry. The computer will then accept the answer and move on to the next question.
- If you wish to correct an entry *after* you have hit return, but before you have confirmed it with an ampersand, simply retype the number and hit return again.
- If you wish to correct an entry *before* you have hit return, use the backspace key (←, upper right on the keyboard) to begin the number again or to rekey part of the number.
- After you have typed the ampersand to confirm an entry, there is no way to correct it—so CHECK EACH ENTRY CAREFULLY BEFORE YOU CONFIRM IT.
- If the word "TEXT" lights up after you have hit the return key, but *before* you have confirmed with an ampersand, retype your entry.
- At the end of the Background and Introduction screens, and at the end of parts I, VII, and VIII, you must type the ampersand to advance to the next screen. IMPORTANT: Sometimes it will be necessary to type the ampersand several times, so if you've typed it and, within a second or two, have not advanced to the next screen, type it again.
- IMPORTANT: *On part II*, if you accidentally confirm a number that was typed incorrectly, stop immediately and tell a proctor.
- On parts I and VII, you may change any entry you wish by moving to the entry with the up or down arrows (to the far right of the keyboard). To move all the way to the beginning of these screens to review all of your entries, press the HOME key (next to the up arrow). DO NOT PRESS THE HOME KEY ON ANY OTHER PART OF THE EXPERIMENT.

Part I—Annual Consumption (Press down arrow to page down.)

Today is January 1, 1987 and you have just turned 35. This is your first day of work. You receive $25,000 today, payment in advance for working over the year. You will continue to work for the next 30 years earning $25,000 each year. On Jan. 1, 2016 you will be 64 and will start your last year of work and receive your last paycheck. Your last day of work is December 31, 2016. After retiring you will live for ten more years and die on December 31, 2026.

You have no initial savings. Below is a list of earnings you receive at each age over your lifetime. At each age please fill in the total amount of money you would choose to spend on consumption during that year.

Before you fill in your consumption choices, we want to make sure you understand how interest on your savings or borrowings is compounded. Since the interest rate is 4 percent, your assets on January 1 of each year are equal to 1.04 times the sum of your assets on January 1 of the previous year plus your earnings on January 1 of the previous year less your consumption on January 1 of the previous year. Thus, if assets last January 1 were $10,000, earnings were $25,000 and consumption was $23,000, then assets this January 1 would equal 1.04 times ($10,000 + $25,000 − $23,000) = 1.04 × $12,000 = $12,480.

Remember, at the end of your life YOU SHOULD NOT END UP IN DEBT. On the other hand, you do not want to leave behind any unspent money. In deciding your consumption at each age, choose, on the basis of what would make you most happy, given what you can afford.

(Type "&" to begin part I.)

Part I—Annual Consumption

Please enter your desired consumption for each year. Enter only numerals, no commas or other punctuation.

Age	Date	Earnings	Consumption
35	Jan. 1, 1987	25000	0
36	Jan. 1, 1988	25000	0
37	Jan. 1, 1989	25000	0
38	Jan. 1, 1990	25000	0

Age	Date	Earnings	Consumption
39	Jan. 1, 1991	25000	0
40	Jan. 1, 1992	25000	0
41	Jan. 1, 1993	25000	0
42	Jan. 1, 1994	25000	0
43	Jan. 1, 1995	25000	0
44	Jan. 1, 1996	25000	0
45	Jan. 1, 1997	25000	0
46	Jan. 1, 1998	25000	0
47	Jan. 1, 1999	25000	0
48	Jan. 1, 2000	25000	0
49	Jan. 1, 2001	25000	0
50	Jan. 1, 2002	25000	0
51	Jan. 1, 2003	25000	0
52	Jan. 1, 2004	25000	0
53	Jan. 1, 2005	25000	0
54	Jan. 1, 2006	25000	0
55	Jan. 1, 2007	25000	0
56	Jan. 1, 2008	25000	0
57	Jan. 1, 2009	25000	0
58	Jan. 1, 2010	25000	0
59	Jan. 1, 2011	25000	0
60	Jan. 1, 2012	25000	0
61	Jan. 1, 2013	25000	0
62	Jan. 1, 2014	25000	0
63	Jan. 1, 2015	25000	0
64	Jan. 1, 2016	25000	0
65	Jan. 1, 2017	0	0
66	Jan. 1, 2018	0	0
67	Jan. 1, 2019	0	0
68	Jan. 1, 2020	0	0
69	Jan. 1, 2021	0	0
70	Jan. 1, 2022	0	0

Age	Date	Earnings	Consumption
71	Jan. 1, 2023	0	0
72	Jan. 1, 2024	0	0
73	Jan. 1, 2025	0	0
74	Jan. 1, 2026	0	0
75	Jan. 1, 2027	YOU ARE NOW DEAD	

Part II—Consumption With Knowledge of Money in Savings Account

We are now going to repeat the previous question, but this time before you tell us how much you wish to consume in a given year we will tell you the amount of savings you have at the beginning of that year. If you are in debt at the beginning of a particular year your savings will be negative. Keep in mind that while you are free to borrow money from the bank, you cannot end up in debt at the end of your life. Also recall that your yearly earnings are $25,000 per year until you retire at the beginning of your 65th year and that you will die when you reach age 75.

(After reading, type "&" to begin part II.)

You are 35 years old. You will earn $25,000 per year until age 65. Your savings in your bank account is $0.00.

How much do you wish to spend to consumption this year?

Age	Money in Savings Account	Consumption	Interest Income	Labor Earnings
35	0		0	25000

(Enter number. Then type "&" to confirm.)

Part III—Consumption With Specified Savings at Selected Ages

We are now going to ask you to imagine you are a particular age and have a certain amount of money in your savings account. Please tell us how much you would spend on consumption at that age, given the savings indicated. The questionnaire will ask you to respond to 16 different age/savings combinations. Be sure to read BOTH age

and savings before responding. Remember, you will continue to work until age 65 earning $25,000 per year.

(After reading, type "&" to begin Part III.)

You are 35 years old. You will earn $25,000 per year until age 65. Your savings in your bank account is $43,500.

How much would you consume at this age?

Age	Money in Savings Account	Consumption	Earnings
35←	43500←		25000
		(Enter number. Then type "&" to confirm.)	

Part IV—Consumption With Different Retirement Ages

Next we want to find out how much you'd spend on consumption if your retirement age were different from 65. We will ask you what you would consume at age 46, with $100,000 in your savings account, if you are to retire at some specified retirement age. We will ask you at 4 different retirement ages.

As usual, your earnings will be 25,000 per year until you reach the given retirement age.

(After reading, type "&" to begin Part IV.)

You are 46 years old. You earn $25,000 per year until retirement. Your savings account balance is $500,000.

How much would you consume at this age if you retire at age 72?

Age	Money in Savings Account	Consumption	Retirement Age
46	500000		72←
		(Enter number. Then type "&" to confirm.)	

Part V—Consumption with Different Lifetime Earnings

Now assume again that you will retire at 65 but that your earnings vary throughout your working life. We will hold your initial savings fixed at $65,000. Then we will show you an earnings profile and ask how much you would consume at 3 different ages, given those

earnings. We will repeat this 3 times, showing you a different earnings profile each time. You will be asked for a total of 9 responses.

(After reading, type "&" to begin part V.)

You are 35 years old, and your savings account balance is $65,000. Your annual earnings are listed below—notice you retire at age 65.

How much would you consume at this age, given these earnings?

Age	Money in Savings Account	Earnings
35←	65000	23200 from age 35 through age 44
	Consumption	47800 from age 45 through age 54
	(Enter number. Then type "&" to confirm.)	32500 from age 55 through age 64

Part VI—Consumption with Different Interest Rates

Next we want to find out how much you'd spend on consumption if the interest rate were different from 4%. We will ask you what you would consume at age 46, with $90,000 in your savings account given the interest rate indicated. We will repeat this 5 times, changing the interest rate each time. Your earnings will be $25,000 per year until age 65.

(After reading, type "&" to being part VI.)

You are 46 years old. You earn $25,000 per year until age 65. Your savings in your bank account is $90,000.

How much would you consume at this age if the interest rate were 0%?

Age	Money in Savings Account	Consumption	Interest Rate
46	90000		0%←
		(Enter number. Then type "&" to confirm.)	

Part VII—Consumption With Changing Interest Rate

Next we want to see how your consumption and saving decisions are influenced by changes in interest rates over the course of your life-

time. Imagine that you are age 45, that you work until 65, earning $25,000 per year, and that you die at age 75. The interest rate you receive on your savings is not, however, fixed. The following table summarizes the interest rate you will face at each age. (They will be repeated on the next screen.)

(After reading, type "&" to begin part VII.)

Part VII—Consumption with Changing Interest Rate

Now assume you are age 45 and will earn $25000 per year, you retire at age 65, and that you will die at age 75.

Please enter your desired consumption for each year, and the interest rate in each case. Type "&" after completing the entire column.

Age	Date	Earnings	Consumption	Interest Rate
45	Jan. 1, 1997	25000	0	2%
46	Jan. 1, 1998	25000	0	2%
47	Jan. 1, 1999	25000	0	2%
48	Jan. 1, 2000	25000	0	2%
49	Jan. 1, 2001	25000	0	2%
50	Jan. 1, 2002	25000	0	2%
51	Jan. 1, 2003	25000	0	2%
52	Jan. 1, 2004	25000	0	2%
53	Jan. 1, 2005	25000	0	4%
54	Jan. 1, 2006	25000	0	4%
55	Jan. 1, 2007	25000	0	4%
56	Jan. 1, 2008	25000	0	4%
57	Jan. 1, 2009	25000	0	4%
58	Jan. 1, 2010	25000	0	4%
59	Jan. 1, 2011	25000	0	4%
60	Jan. 1, 2012	25000	0	4%
61	Jan. 1, 2013	25000	0	6%
62	Jan. 1, 2014	25000	0	6%
63	Jan. 1, 2015	25000	0	6%
64	Jan. 1, 2016	25000	0	6%

Age	Date	Earnings	Consumption	Interest Rate
65	Jan. 1, 2017	0	0	6%
66	Jan. 1, 2018	0	0	6%
67	Jan. 1, 2019	0	0	6%
68	Jan. 1, 2020	0	0	3%
69	Jan. 1, 2021	0	0	3%
70	Jan. 1, 2022	0	0	3%
71	Jan. 1, 2023	0	0	3%
72	Jan. 1, 2024	0	0	3%
73	Jan. 1, 2025	0	0	3%
74	Jan. 1, 2026	0	0	
75	Jan. 1, 2027		YOU ARE NOW DEAD	

Part VIII—Ranking Different Lifetime Consumption Profiles

Again assume you are age 35 and will earn $25,000 per year until you retire at age 65, and that you will die at age 75.

Each of the following consumption plans will leave you with exactly zero dollars on the day you die. Rank them from 1 to 5, giving 1 to your most preferred and 5 to your least preferred. (When finished, type "&" to exit.)

Rank

A. $21841 per year, every year

B. $16008 at age 35, growing 2% per year thereafter

C. $11240 at age 35, growing 4% per year thereafter

D. $28592 at age 35, falling by 2% per year thereafter

E. $23420 from age 35 until age 65, then $10921 from 65 to 75.

Consumption in Selected Years

Age	A	B	C	D	E
35	21841	16008	11240	28592	23420
46	21841	19905	17303	22895	23420
65	21841	28997	36455	15597	10921
74	21841	34654	51887	13004	10921

Part IX—Build Your Own Consumption Path

You have 20 points to distribute among the age ranges to show the relative amounts you'd like to consume at various times in your life. For example, if you wish to consume the same amount in every year, put "5" in each column. If you'd rather consume more while you're young, and less while you're old, enter larger numbers first, then smaller numbers. The program will translate the numbers you type into consumption in each age range. You can modify your numbers until you're satisfied with your lifetime consumption path. Remember, you can type any numbers you like provided they add up to twenty. (NOTE: You still earn $25,000 per year until retiring at age 65.)

(Type "&" to begin Part IX.)

Allot your twenty points to the four decades of your life. You still earn $25,000 per year until retirement at age 65. Below the numbers you type will appear a translation of your points into consumption for the decade. ONCE YOU'VE ENTERED YOUR POINTS, TYPE "!" FOR TRANSLATION. YOU MAY DO THIS AS MANY TIMES AS YOU WISH. WHEN YOU ARE FINALLY SATISFIED WITH THE CONSUMPTION PATHS YOU HAVE CONSTRUCTED, TYPE "&" TO FINISH THE EXPERIMENT.

Interest/AGE	35–44	45–54	55–64	65–74
.04	20	0	0	0
	53299	0	0	0
.08	20	0	0	0
	41944	0	0	0

Note

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