Estimating preference parameters in individual financial decision-making

Teppa, F.

Publication date:
2003

Document Version
Publisher's PDF, also known as Version of record

Estimating Preference Parameters in Individual Financial Decision Making

Estimating Preference Parameters in Individual Financial Decision Making

Proefschrift

ter verkrijging van de graad van doctor aan de Universiteit van Tilburg,op gezag van de rector magnificus, prof. dr. F. A. van der Duyn Schouten, in het openbaar te verdedigen ten overstaan van een door het college voor promoties aangewezen commissie in de aula van de Universiteit op vrijdag 24 january 2003 om 10.15 uur door

Federica Teppa

geboren op 25 maart 1971 te Torino, Italie.

PROMOTOR: prof. dr. A. Kapteyn
COPROMOTOR: dr. R.J.M. Alessie

Acknowledgment

In September 1998 I became a PhD student at the CentER for Economic Research in Tilburg, The Netherlands. The academic output of the four years spent at CentER is the present thesis, that would not be as such without the inestimable contributions of my supervisors. I don't have appropriate words to express all my gratitude to Arie Kapteyn, who never hesitated to cut some of his very busy time out to supervise and work on this thesis. I have learned a lot from him and I will always appreciate his generosity, patience and encouragement. I am also extremely grateful to Rob Alessie, for the very productive and pleasant time spent in Tilburg and in Amsterdam: his kindness and disponibility have been something unusual. Moreover, many thanks go to Monika Buetler, who involved me in one of her research projects in Switzerland. Interacting with her has been challenging and successful: I benefited from and enjoyed a lot working with her. I look forward to continuing our collaboration. I have to deeply thank Elsa Fornero for suggesting me to apply to Tilburg University, an inspiring, stimulating and dynamic working place: it is a great pleasure to have her in my committee. I am also very happy and honored that Arthur van Soust and Jan van Ours are joining the thesis committee.

I gratefully acknowledge funding from the TMR "Savings and Pensions" Network project (contract number ERBFMRXCT960016) that gave me the opportunity to participate in many conferences and to visit Arie Kapteyn in Santa Monica by financing all the trips. I thank all the TMR conferences' participants for the stimulating and lovely time spent together. The present thesis has greatly benefited from the discussions and interactions at conferences and seminars over these four years.

My stay in Tilburg has been extremely pleasant thanks to many people: my office mates Maria Montero e Rossella Bargiacchi, my colleagues at the 8th floor, the aio-uitjes participants and many more. I am deeply indebted to Bas 'Sherlock' van Groezen, who encouraged and carefully supervised a long applied research activity whose outcome is an empirical paper on the role of habits and the inefficiency of signals, forthcoming in *The Journal of Boring Behavior*. Though the dataset consisted of only one observation, many puzzling conclusions could be drawn from our detailed time-series analysis. All the secretaries at CentER have constantly maintained an enjoyable atmosphere, so that since the beginning I felt myself at home. A special thank goes to Marie Louise Kemperman, my personal "problem solver", always ready to provide me with a quick and reliable solution: her office has been a centre of gravity for me over these years.

My gratitude to Trea and Dietmar for providing me with a home during the first days of my stay in Tilburg and for taking care of the most important purchase in the Netherlands: a bike. Even more gratitude to Claudio, the one and only painting mathematician crossing borders in Northern Europe, for his generosity and sensibility, for his extraordinary patience and his unshakable linearity. I have never been homesick thanks to Donatella, Wilma, Louis-Pierre and Annette: their sweet and warm presence have been of great moral and material support. I wish all the best for them.

Finally, my biggest thanks go to my family: my parents and my brother have constantly represented an inexhaustible source of cheerfulness and love.

Tilburg, August 2002.

Contents

Chapter 1

Introduction

This thesis deals with individual financial decision making. Decision making is the process of choosing a preferred option from among a set of alternatives. It often begins at the information-gathering stage and goes on through deliberation, until the final act of choosing. The study of decision making is an interdisciplinary one involving economics, political science, sociology, psychology, statistics, and philosophy.

Individual behavior has been traditionally studied in economics by means of the **rational-choice model**, that assumes that agents maximize some objective function under the constraints they face in pursuit of their self-interest. The subject has been developed in decision theory (Luce and Raiffa, 1957), decision analysis (Raiffa, 1968), game theory (von Neumann and Morgenstern, 1953), political theory (Mueller, 1989), psychology (Kahneman, Slovic and Tversky, 1982) and economics (Debreu, 1959; Henderson and Quandt, 1980). The concept of utility enters economic analysis typically via a mathematical representation of an individual's preferences over alternative bundles of consumption goods or, more generally, over goods, services, and leisure. The concept of rational behavior has the advantage of making the analysis of individual behavior more tractable than a less structured assumption would permit and can be interpreted in two ways. First, it allows to derive optimal economic behavior in a normative sense. Second, models of rational behavior can be used to explain and predict actual and observed economic behavior. The theory of subjective expected utility (Savage, 1954) is the central element of the neoclassical theory of rational economic behavior. As such, it is the most important example of a theory of rational behavior. Its basic assumptions are that choices are made:

- among a given, fixed set of alternatives;
- with (subjectively) known probability distributions of outcomes for each alternative;
- in such a way as to maximize the expected value of a given utility function.

While these assumptions are convenient for many purposes, they may not fit empirically many situations of economic choice. A growing number of economists have become aware of the fact that in order to make their models more relevant and realistic they must take into account (and borrow) insights and methodologies from different research fields, namely psychology and other social sciences. This is the subject of the theory of **bounded rationality** and the research interest of **behavioral economics**. The expression "bounded rationality" (Simon, 1955) is used to designate models of rational choice that take into account the cognitive limitations of both knowledge and cognitive capacity.

Bounded rationality is a central theme in behavioral economics. It departs from one or more of the neoclassical assumptions underlying the theory of rational behavior, that is, theories of bounded rationality relax one or more assumptions of standard expected utility theory. Behavioral economics is the application of psychological theory and research to economics. It investigates what happens in markets in which some of the agents display human limitations and complications. Research in behavioral economics has adopted specific methodological approaches that complement traditional statistical and econometric tests of economic models. For example, experiments are commonly used in behavioral economics, and survey data are also becoming more and more important in the process of learning about individuals' actual decision-making processes.

As already mentioned, this thesis is focused on the empirical study of financial decision making at the individual level. The analysis of concepts such as risk attitude, intertemporal choice, time preference and habit formation is here implemented according to a positive approach, based on empirical observation and on experimental studies of choice behavior. The estimation of (some of) the parameters governing people's preferences provides additional findings in a large body of literature where there is still room for debate about how agents make their choices in reality. The thesis consists of four chapters, that can be read independently from each other and whose content is described in section 1.1. The empirical evidence comes from several sources, described in section 1.2.

The starting point of all the chapters of the thesis is the standard rational-choice model. Agents are assumed to have a preference ordering defined over risky prospects for which a number of axioms hold. Risky alternatives can be evaluated under these assumptions by means of the expected utility function. The curvature of the utility function is a measure of risk attitude. As usual in the literature about measuring risk attitude, the thesis provides evidence about risk aversion by means of information obtained from a survey, where people are asked how they would choose among risky prospects. Risk attitude is related with individual characteristics, namely age, gender and level of education. Besides, measures of risk attitudes are incorporated into a household portfolio allocation model, which explains portfolio shares, while accounting for incomplete portfolios.

Most of this thesis is devoted to provide some additional empirical evidence on the intertemporal discounting process. Generally, in both psychology and economics most of the empirical findings have led to the conclusion that value and time exhibit a negative relation, so that the value of a certain good is discounted as a function of the time when it will be received. Ample evidence has accumulatated for the fact that the conventional intertemporally additive utility formulation with exponential discounting provides an inadequate model of dynamic choice, so that alternative formulations have been developed. Two important strands are, what might be called, changing-tastes models and self-control models. Changing tastes models account for the fact that preferences change over time so that, as time passes, a consumer may revise his consumption plans. Self-control has been investigated by means of models where the individual is seen as an organization, so that the problem of self-control is basically the same as the agency conflict between the owner and the manager of a firm. It is therefore not surprising that most of the work done in this field of research is based on a game-theoretic analysis. Two different empirical approaches have been developed in the literature in order to estimate individual preference parameters: the revealed preference approach and, what we shall call, the experimental approach. The first method consists of making a set of assumptions on the true individuals' preferences, observing the actual behavior and inferring the preference parameters. The experimental method consists of posing direct choices to respondents, which may involve real or hypothetical payoffs. The advantage of experiments is that one does not have to model the full environment in which agents operate (particularly constraints and uncertainty), but rather that one can fully specify scenarios himself. On the other hand, of course, one may wonder how seriously respondents are trying to give honest answers, in particular to questions that have no consequences for themselves (hypothetical payoffs).

The thesis also focusses on habit formation, meaning that consumers' current utility depends in part on current consumption relative to a habit stock determined by past consumption. This has been recently used to improve the predictions of time-separable models in several fields, such as saving behavior under uncertainty. Habits have been particularly useful in three domains of macroeconomic theory. First, some authors have studied different formulations of habit formation may improve our understanding of the equity premium puzzle. Abel (1990) and Constantinides (1990), among others, show that adding habit formation to a standard exchange model economy, the equity premium puzzle (Mehra and Prescott, 1985) disappears. Second, this class of references has been proposed to analyze the observed relationship between saving and growth. Empirical evidence suggests that both across countries and across households the income growth rate has a positive and significant effect on the savings rate (Edwards, 1995; Carroll and Weil, 1994). Carroll, Overland and Weil (2000) modify the standard Ak model to display habit formation and they show that the model successfully replicate the positive response of the savings rate to the income growth rate. Third, habits may be necessary to explain the "excess smoothness" of aggregate consumption at high frequencies. Fuhrer (2000) is able to replicate slow and hump-shaped reactions of consumption to monetary and other shocks in a theoretical model by introducing habit formation in the consumption function. If the utility out of consumption does not only depend on the level of consumption but also on the change of consumption between the current and the last period, a shock to income will lead to a delayed reaction in consumption. The reasoning for this delay is due to households anticipating the (negative) impact of current consumption on future marginal utility of consumption. This implies the gradual response of consumption to a shock in income, replicating the hump shaped response found in the data.

In most of the empirical findings reported in this thesis the predictions from the rational-choice model are confirmed by the data. However, we also find that in some case actual behavior departs (at least partially) from such predictions, so that bounded rationality seem to provide a better explanation for actual individual decision making: whenever people's choices deviate from the assumptions of the rational theory, economic research in decision making needs to borrow from other disciplines concepts that account for empirical counterintuitive findings.

1.1 Overview of the thesis

This section provides a summary of the content of the thesis's chapters.

Chapter 2 estimates discount rates, intertemporal substitution elasticities and habit persistence parameters from data where respondents are asked to choose between hypothetical consumption streams in a succession of survey questions. The chapter belongs to a growing literature on the use of hypothetical questions in surveys devoted to the estimation of parameters that are often hard to identify from revealed preference data. Within this literature, the closest reference is the Barsky, Juster, Kimball and Shapiro's paper (QJE, 1997) which addresses the same question with a slightly different approach using US data from the Health and Retirement Survey. The procedure followed in the chapter consists of parameterizing life time utility of each path the respondent is presented with as a function of the level and growth rate of consumption across years (both of which are allocated randomly for each path for each respondent) as well as of the parameters representing the subjective discount rate, the coefficient of risk aversion and, in the latter part of the chapter, the degree of habit persistence. A logit framework is then employed to estimate the parameters of interest by assuming the respondent chooses the hypothetical path that would provide her the highest lifetime utility. Models with habit formation appear to be superior to models with intertemporally additive preferences. The estimate of the intertemporal elasticity of substitution appears to be quite robust with respect to the different assumptions regarding habit formation. The coefficient of relative risk aversion however changes substantially across specifications. In itself this demonstrates the importance of breaking the connection between the intertemporal elasticity of substitution and risk aversion in intertemporal models. The main finding of our empirical analysis may be the rejection of intertemporal additivity.

It is well known that people tend to avoid risk. The more they dislike it, the higher their demand for insurance. Moreover, risk aversion also determines their demand for risky investments, like stocks. Yet until now there has been little direct evidence about people's attitudes towards risk. Chapter 3 investigates individual risk attitude in a model of household portfolio allocation. Several different measures of risk attitudes are used, including questions on choices between uncertain income streams suggested by Barsky et al. (1997) and a number of ad hoc measures. As in Barsky et al. (1997) and Arrondel (2000), individual variation in the risk aversion measures are first analyzed and explained by background characteristics (both "objective" characteristics and other subjective measures of risk preference). Next the measured risk attitudes are incorporated into a household portfolio allocation model, which explains portfolio shares, while accounting for incomplete portfolios. We build a structural model with endogenously switching regimes, where each regime is characterized by a particular asset ownership pattern. The model has two components: the first component determines the regime, and the second component describes portfolio shares of assets conditional on the regime. Our results show that the Barsky et al. (1997) measure, though being the one with a firmer basis in economic theory, has little explanatory power, whereas *ad hoc*, more intuitive measures of risk aversion do a considerably better job in explaining portfolio choice. We provide a discussion of the reasons for this finding.

In a recent article, John T. Warner and Saul Pletter (AER 2001) estimate personal discount rates from a choice between an annuity and a lump sum capital payment in military downsizing programs. From this natural experiment the authors find very high estimates of personal discount rates (up to 30%). In chapter 4 we analyze a similar choice between an annuity and a lump sum capital option upon retirement in Swiss pension funds, which involve decisions over substantially larger sums. We find that the role of personal characteristics (such as gender, marital status, age at retirement, number of children) on the choice seems to be somewhat overshadowed by other components, namely company fixed effects and the conversion factor, that is the factor at which is capital is translated into an annuity. In contrast with Warner and Pleeter's results, we find that the discount rate seems to play essentially no role in explaining the individual's choice. This analysis seems to suggest that when taking financial decisions people choose on the basis of easy variables (the conversion factor, in this particular case) rather than of more complicated and sophisticated ones. This finding may be explained in a bounded rationality framework, that stresses the limited cognitive abilities that constrain human problem solving. The ideal of rational decision making requires choosing as to maximize a measure of expected utility that reflects a complete and consistent preference order and probability measure over all possible contingencies. This requirement appears too strong to permit accurate description of the behavior of realistic individual agents studied in economics.

Chapter 5 focuses on the role of habit formation in individual preferences over consumption and saving. In this chapter we estimate a model based on Alessie and Lusardi's (1997) closed-form solution of saving,[1] where saving is expressed as a function of lagged saving and other regressors, such as age, gender, level of education, household composition, expected and realized income changes. Our empirical results show evidence in favor of habit formation. This conclusion is not in line with some earlier literature. Dynan (2000) and Guariglia and Rossi (2001) find negative estimates of the habit formation coefficient. Their results come from the Euler equation for consumption rather than from a closed form solution. We argue that the data they use in their analysis refers to consumption expenditures (rather than savings) which is presumably measured with considerable error. Such measurement errors may be responsible for a strong spurious negative correlation between differences in current (Δc_{it}) and past consumption levels (Δc_{it-1}). As a consequence, the OLS estimate of the habit formation parameter γ is biased towards a "negative number". Moreover, a second reason to use the closed form solution as a basis of the empirical model is that it embodies more information about the habit formation model than the Euler equation. Therefore, the closed form solution allows for a more powerful test of the validity of the habit formation model than the Euler equation approach. Moreover, we find evidence in favor of a short planning horizon and liquidity constraints. More theoretical research seems to be needed in order to investigate the joint impact of liquidity constraints and habit formation.

[1] Alessie and Lusardi (1997) consider models of habit formation and derive closed-form solutions for consumption and saving under certainty equivalence and uncertainty. They find evidence for habit formation for both consumption and saving.

1.2 Datasets used for the empirical analysis

All the remaining chapters in this thesis contain an empirical part devoted to the estimation of individual preference parameters. Chapters 2 and 5 are based on the CentER Savings Survey; chapter 3 exploits the CentER Saving Survey and the CentERpanel; chapter 4 uses an *ah hoc* Swiss database. In this section we provide a brief description of such datasets.

1. *CentER Savings Survey (CSS).* Formerly known as the VSB panel, the CSS is a panel survey started in 1993 and run every year. Until 1997, the CentER Savings Survey consisted of two samples. The first sample (REP) was intended to be representative of the Dutch population, even if the actual REP samples are not completely representative because of survey non-response; it consists of some 2000 households in each wave, including refreshment samples compensating for panel attrition. The second sample (HIP) was representative of the top 10 percent of the income distribution and initially it contained some 900 households. In 1998 most respondents of the second sample stopped, so that since that year on the CSS includes only the REP.

   The CentER Savings Survey consists of five questionnaires: work and pensions, accommodation and mortgages, income and health, assets and liabilities, economic and psychological concepts. The questionnaires are sent to the respondents by modem, the respondents fill in the questionnaires at their home computers, and the answers are returned in the same way. This means that the questionnaires are answered without the interference of an interviewer and the respondents can answer the questionnaires at a time that is convenient for them.

   For our purposes we focus mainly on the assets and liabilities questionnaire and the economic and psychological concepts. The former provides detailed information about forty asset and debt categories, both financial and real[2]. The economic and psychological concepts questionnaire represents a very rich set of questions about several topics, such as, among others, personal characteristics, household income, expectations about future income, attitude towards saving and saving behavior, risk perception and risk aversion, expectations for the future and comparison with the current situation, planning of financial matters.

[2] A detailed description of these assets and liabilities is provided by Alessie, Hochguertel and van Soest (2002).

2. *The CentERpanel.* The CentERpanel, established in 1991, is an Internet-based telepanel. The CentER Saving Survey described above is part of the CentERpanel, as the households members of the latter telepanel are also respondents to the CSS. In fact, questionnaires from CentERpanel focus on a wider variety of subjects, so that information from the CSS can be combined with answers given by the same households to other questions included in the CentERpanel.

3. *A pilot Swiss database.* During the academic year 2000/2001, approximately 120 large and medium sized Swiss pension funds were contacted by mail with a short description of a research project. About half of the addressee replied and 15 of them were ready to provide their data. Due to data limitations and other (technical and organizational) problems, a database could be established for 9 companies, both public and private, active in several industrial branches. The dataset consists of 1449 observations.

Chapter 2

Hypothetical Intertemporal Consumption Choices

Time preference has been extensively measured through survey techniques. In general, respondents face a hypothetical situation involving different amounts of money (or some other desirable good) at different points in time and are asked to either express a preference for one of the alternatives or to provide a trade-off (how much money does one require to postpone the receipt of a certain amount for instance). Discount rates measured in this way were found to be negatively correlated with future time orientation and positively correlated with big spending (Thomas and Ward, 1979). Kurz et al. (1973) asked a sample of participants in the Seattle and Denver Income Maintenance Experiments a series of hypothetical questions such as: "What size bonus would you demand today rather than collect a bonus of $100 in 1 year?". They found a mean rate of time preference between .36 and .76, and between .40 and 1.22 for whites and for blacks, respectively.

Although these rates of time preference may seem implausibly high, high rates are also found in revealed preference studies. In a well-known study Hausman (1979) used individual household data on the purchase and utilization of room air conditioners to estimate the intertemporal discount rates used by consumers in order to evaluate the trade-off between present and future costs. He found an estimated average annual discount rate of 26.4% (clearly above any relevant interest rate) and an inverse relation with income. Loewenstein and Thaler (1989) cite a number of other studies that find even larger discount rates. Explanations that have been offered include information barriers and liquidity constraints. Further explanations have been provided by Kooreman (1995), whose main conclusion is that if risk-neutral consumers anticipate a random lifetime of a durable, the assumption of a deterministic lifetime results in an upward bias, as large as 35%, of estimated discount rates.

Donkers et van Soest (1999) and Donkers et al. (1999) used data from the VSB panel survey[1] of Dutch households in order to elicit information about subjective measures of time preference, financial decisions and risk attitudes. Their main results are that the rate of time preference is negatively related to age and that women are more patient than men; the subjective time preference rate is furthermore positively related to the decision to hold risky assets.

In models of dynamic choice increasing attention is given to the concept of self-control. This has been investigated by means of models where the agent is assumed to be both a farsighted planner and a myopic doer. The individual is seen as an organization, so that the problem of self-control is basically the same as the agency conflict between the owner and the manager of a firm. It is therefore not surprising that most of the work done in

[1] Now called the CentER Savings Survey (CSS).

this field of research is based on a game-theoretic analysis. Some of the applications of the principal-agent model has been investigated by Thaler and Shefrin (1981), particularly in the study of individual saving behaviour. The work by Laibson (1997) squarely falls into this category.

Our study follows Barsky, Juster, Kimball, and Shapiro (1997) (BJKS from now on) in using observed hypothetical choices between different consumption patterns to estimate both the rate of time preference and the elasticity of intertemporal substitution. As a theoretical framework we take the conventional intertemporally additive utility model as a starting point. We then extend the model by allowing for habit formation. By using hypothetical questions, the issue of self-control does not arise. The hypothetical nature of the questions allows the respondent to our questions to be a planner rather than a doer. Also, uncertainty is not part of the framework in which questions are asked. So, when we speak of relative risk aversion this refers to nothing else than the curvature of the intratemporal utility function. The goal of the chapter is to investigate the structure of intertemporal preferences over consumption streams in as clean an environment as possible. Thus we abstract from uncertainty and present respondents in a survey with straightforward choices that do not involve complicated utility maximization tasks.

Section 2.1 describes the dataset we used for the experiment and presents the most relevant summary statistics. The basic model (with intertemporally additive utility) is presented in Section 2.2. In the same section we also present estimation results for this model. Habit formation is introduced in Section 2.3, where two model specifications are described, as well as the estimation outcomes for these two models. One of the distinguishing features of the conventional intertemporally additive utility model is the inverse relationship between the IES and the relative risk aversion parameter (in our context without uncertainty merely interpreted as a measure of the concavity of the utility function). Introduction of habit formation breaks this relation. Section 2.3 also includes a derivation of the IES in the model with habit formation. Section 2.4 concludes the chapter.

2.1 The Dataset

In the empirical analysis we use data from the *CentERpanel*. The CentERpanel comprises some 2000 households in the Netherlands. The members of those households answer a questionnaire at their home computers every week. These computers may either be their own computer or a set-top box provided by CentERdata, the agency running the panel. The CentERpanel is representative of the Dutch population. In the weekends of August 7-10 and August 14-17 of 1998 a questionnaire was fielded with a large number of subjective questions on hypothetical choices. The questionnaire was repeated in the weekends of November 20-23 and November 27-30 of 1998 for those panel members who had not responded yet. For reasons that will become clear below a very similar questionnaire was fielded among the members of the CentERpanel in late January of 2002. The questions we use present respondents with five different hypothetical consumption paths and then ask them to choose one of them. A typical question reads as follows:

Now imagine that you (and your partner) decide to take financial advice and set up an expenditure plan, starting now and ending when you are 65 *years old. The financial advisor tells you that, in your situation, there are a number of options. These options will be presented on the screen below.*

Please indicate by selecting a number, which expenditure pattern you would prefer. When making this choice, please consider your family situation to remain unchanged.

Please indicate your preferred expenditure pattern by selecting a number.

Age\Pattern	**1**	**2**	**3**	**4**	**5**
52	7691	7017	6409	5659	4768
54	7295	6803	6409	5853	5226
55	7105	6699	6409	5953	5472
57	6739	6495	6409	6157	5999
59	6392	6297	6409	6368	6576
60	6225	6201	6409	6476	6885
62	5904	6012	6409	6698	7547
63	5750	5920	6409	6812	7902
65	5454	5740	6409	7045	8662

Select expenditure pattern 1, 2, 3, 4 or 5.

After this question, three more, similar, questions are asked. The ages listed in the first column vary depending on the respondent's characteristics. In particular, the final age (denoted by L) is equal to 65, if the respondent is currently younger than 56 (as in the example reported above); L is equal to 75, if the respondent is currently between 56 and 65; L is equal to 85, if the respondent is currently between 66 and 75. The questions are not posed to respondents older than 75. The interval between the respondent's own age and L is divided in (almost) equal parts. Respondents only see numbers and not a picture of consumption profiles.

2.1.1 The data generating process

The various consumption patterns have been generated as follows. Let y denote the respondent's self-reported after-tax household's monthly income. It is the sum of the net income of each household member, based on information that was provided by the respondent in earlier questionnaires. Let ϵ be a uniformly distributed random variable on $[.8, 1.2]$. For each respondent we draw one value from the distribution of ϵ and compute $C = .9y\epsilon$. C is the flat consumption path that is given to the respondent as one of the possible choices (the middle column in the question cited above). The remaining consumption paths are derived from C as follows.

Draw four random variables: α_1 from $U[-.05, -.025]$, α_2 from $U[-.025, 0]$, α_3 from $U[0, .025]$, and α_4 from $U[.025, .05]$. These random variables are *consumption growth rates*. Let the current age of a respondent be l (i.e. *52* in the question). Furthermore let c_l^i be the consumption level at age l in path $i = 1, ..., 4$ (the construction of c_l^i is described below). Then the consumption level in path i at any given age τ between l and L is given by $c_\tau^i = c_l^i.(1 + \alpha_i)^{\tau - l}$. In other words, a consumption pattern is completely characterized by its initial value c_l^i and the growth rate α_i. It remains to describe the way the initial values c_l^i are generated.

The following somewhat artificial procedure has been adopted. Let r_i be a random *interest rate* drawn from a uniform distribution on $[-5, 5]$. Also the r_i are respondent specific. Given the interest rate r_i and the growth rate α_i we choose c_l^i in such a way that the present discounted value of the consumption stream $\{c_\tau^i = c_l^i(1 + \alpha_i)^{\tau - l}\}_{\tau=l}^L$ is equal to the present discounted value of the constant consumption pattern C. In other words we impose:

$$c_l^i + c_l^i \frac{(1+\alpha_i)}{1+\frac{r_i}{100}} + ... + c_l^i \frac{(1+\alpha_i)^{\tau-l}}{(1+\frac{r_i}{100})^{\tau-l}} + ...c_l^i \frac{(1+\alpha_i)^{L-l}}{(1+\frac{r_i}{100})^{L-l}} \tag{2.1}$$

$$= C[1 + \frac{1}{1+\frac{r_i}{100}} + ... + \frac{1}{(1+\frac{r_i}{100})^{\tau-l}} + ... \frac{1}{(1+\frac{r_i}{100})^{L-l}}] \tag{2.2}$$

Define $A_i \equiv 1 + \alpha_i$ and $R_i \equiv \frac{1}{1+\frac{r_i}{100}}$. Then the equality can be written as

$$c_l^i[1 + A_i R_i + ... + (A_i R_i)^{\tau-l} + ... + (A_i R_i)^{L-l}] = C[1 + R_i + ... + R_i^{\tau-l} + ...R_i^{L-l}] \tag{2.3}$$

Solving for c_l^i yields

$$c_l^i = C \frac{1 - A_i R_i}{1 - R_i} \frac{1 - R_i^{L-l+1}}{1 - (A_i R_i)^{L-l+1}} \tag{2.4}$$

The procedure followed ensures that respondents are faced with choices that do not deviate wildly from their own consumption level. We should note that since the respondents are not told the values of α_i and r_i, these values are in themselves irrelevant for the way in which the respondents perform the task of selecting consumption paths. They can in principle infer the value of α_i directly from the consumption paths shown to them, but the value of r_i is only of use if for some reason a respondent wanted to engage in the exercise of calculating the internal rate of the return of each of the consumption paths that equates the PDV of the the paths. There is no obvious reason why a respondent would want to do that, since the task itself does not allow for borrowing or lending.

Respondents are asked to perform the task illustrated above four times. The tasks refer to different realizations of consumption paths generated by different draws from the distributions of α_i and r_i. To be sure, the growth rates and interest rates that generate the consumption paths vary across respondents and across the four tasks. The same is true of the parameter ϵ which determines the constant consumption path C. Finally, respondents are explicitly told that the questions are asked in a zero-inflation setting.

2.1.2 Descriptive Statistics

We will use the data from the 2002 experiment. An earlier version of this chapter used the 1998 data. As one can see from the description of the way in which the tasks were generated, the first two consumption patterns presented are always downward sloping, whereas consumption patterns 4 and 5 are always upward sloping. One should probably suspect that not all respondents are equally conscientious in carrying out the task of selecting the optimal consumption path. One way in which this may show up is in "routine selection". For instance, respondents may always pick the first consumption path or always the middle one, etc. This may systematically bias parameter estimates. If for instance many respondents would tend to pick the first consumption path this would show up in our analysis as a preference for downward sloping consumption profiles. The obvious remedy is to randomize the order in which the patterns are presented. In the 1998 data no randomization took place. The motivation for collecting the 2002 data was precisely to correct this omission. Hence in the 2002 data the order in which consumption paths are presented is randomized across each task.

The sample consists of 1545 observations. Households may have multiple respondents, namely the head of household and the spouse. We constructed three levels of education: the "low level of education" consists of primary school, low-level high school, junior high school, junior vocational training, special low-level education and apprentice system; the "middle level of education" consists of senior high school and senior vocational training; the "high level of education" consists of vocational colleges and university education. There are 857 males and 688 females and their ages range from 21 to 76. More than 75% of the sample respondents have a partner. The distribution across the three education levels is fairly uniform (Table 2.1).

Table 2.1: *Distribution of sample respondents across age classes*

Age classes	Gender		Level of Education			Marital status	
	Fem.	Males	Low	Middle	High	Single	Married
22-32 yrs	121	89	25	85	100	76	134
33-43	227	231	108	189	161	103	355
44-55	185	268	123	154	176	95	358
56-66	99	155	91	65	98	48	206
67-75	56	114	64	47	59	37	133
Total	688	857	411	540	594	359	1186

Table 2.2 presents the frequency with which certain columns are chosen. One observes that the choice of columns is distributed fairly uniformly, with perhaps a slight preference for the first and the third columns.

When considering the possibility of "routine selection" we find that 31 out of the 1545 respondents choose the first column across all four tasks. In no other case do we

Table 2.2: *Frequency of consumption patterns choice*

Cons. pattern	Question 1		Question 2		Question 3		Question 4	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
1	379	24.53	340	22.01	312	20.19	294	19.03
2	281	18.19	296	19.16	305	19.74	283	18.32
3	337	21.81	341	22.07	319	20.65	340	22.01
4	259	16.76	276	17.86	310	20.06	311	20.13
5	289	18.71	292	18.90	299	19.35	317	20.52
Total	1545	100	1545	100	1545	100	1545	100

find that a respondent always chooses the same column across the four tasks. This can be contrasted with the results of the 1998 data when we found that almost half of the respondents chose the same column across the four tasks.

2.2 The Basic Model

As a starting point we model the choice of consumption path as the result of maximizing an intertemporally additive utility function. That is, a respondent prefers a sequence of consumption levels, $(c_{1,}..., c_T)$ to an alternative sequence, $\left(c'_{1,}..., c'_T\right)$, if and only if

$$\sum_{t=l}^{L} \phi_t u(c_t) > \sum_{t=l}^{L} \phi_t u(c'_t), \tag{2.5}$$

where $u(c)$ is a concave utility function and ϕ_t is the weight given to utility in period t. Given that l is equal to the respondent's own age, we can interpret period l as being the present, whereas L is the period in which the respondent either turns 65, or 75, or 85. Thus, depending on a respondent's age, the time period over which the consumption path is defined will vary. For instance, if a respondent is 40, the time period will cover 25 years: 40-65. If a respondent is 75 years of age, the time period will cover only 10 years: 75-85. The wording of the question does not specify the consumption level in years in between the ages specified. We will interpret the consumption levels in the questions as representative of a smooth path from l to L. Given the data generating process, the utility of a consumption path can be written as a function of the parameters of the data generating process, as we will see below. In order to arrive at an estimable model, we make a number of additional assumptions. To begin with we assume exponential discounting; that is, the utility of a consumption path is written as:[2]

$$\bar{u} \equiv \sum_{t=l}^{L} (1+\delta)^{-t+1}\, u(c_t), \tag{2.6}$$

where δ denotes the discount rate. To allow for random variation in choices (for instance due to non-observable variation in preferences), we add an i.i.d. extreme value distributed error term to the utility function:

$$u_i^* = \bar{u}_i + \varepsilon_i \qquad p = 1, ..., 5 \tag{2.7}$$

where u_i^* represents the level of utility associated with consumption path i. Consumption pattern i is chosen (which we denote as $d_i = 1$) whenever it yields a level of utility greater than the one associated with all other paths. Formally, this means that

$$d_i = \begin{Bmatrix} 1 \text{ if } u_i^* > u_q^* \;\; \forall q \neq i \\ 0 \text{ otherwise} \end{Bmatrix} \tag{2.8}$$

According to this model we then have the familiar logit form for the probability that consumption path i is chosen:

$$\Pr(d_i = 1) = \frac{\exp(\bar{u}_i)}{\sum_{j=1}^{5} \exp(\bar{u}_j)} \tag{2.9}$$

To close the model, we specify the form of the instantaneous utility function u and we exploit the specifics of the data generating process. For the instantaneous utility function we adopt the CRRA-specification:

$$u(c) \equiv (1-\rho)^{-1} c^{1-\rho} \tag{2.10}$$

The parameter ρ is the coefficient of relative risk aversion and $\frac{1}{\rho}$ is the IES. As mentioned above, we can write the utility function (2.6) as a function of the underlying parameters of

[2] Although we will later generalize this model to allow for habit formation, we will maintain the assumption of exponential discounting throughout. The motivation for this is that in the hypothetical and long term planning context that we study here, issues of self-control are much less likely to arise. In that sense the results presented do indeed refer to dynamic choices over a long horizon and not to short term intertemporal trade offs.

the data generating process. Recall that the consumption at age τ is equal to $c_\tau^i = c_l^i A_i^{(\tau-l)}$, where $A_i \equiv 1+\alpha_i$. Inserting this into (2.6) and using the CRRA specification (2.10) we obtain for the intertemporal utility function:

$$\begin{aligned} \overline{u} &= \sum_{\tau=l}^{L}(1+\delta)^{l-\tau}\frac{1}{1-\rho}(c_l^i A_i^{\tau-l})^{1-\rho} = \frac{(c_l^i)^{1-\rho}}{1-\rho}\sum_{\tau=l}^{L}(1+\delta)^{l-\tau}(A_i^{\tau-l})^{1-\rho} \\ &= \frac{(c_l^i)^{1-\rho}}{1-\rho}\sum_{\tau=l}^{L}\Phi_i^{\tau-l} = \frac{(c_l^i)^{1-\rho}}{1-\rho}\frac{1-\Phi_i^{L-l+1}}{1-\Phi_i} \end{aligned} \tag{2.11}$$

where $\Phi_i \equiv \frac{A_i^{1-\rho}}{1+\delta}$.

Each respondent is asked to choose four times among five consumption patterns. Thus we observe four choices per respondent. Estimation of the underlying parameters (δ, ρ) by maximum likelihood is straightforward.[3] It is worth mentioning that our methodology differs from the one adopted by BJKS, as these authors estimate the rate of time preference and the intertemporal elasticity of substitution by means of the Euler equation deriving from a standard formulation of the consumer's maximization problem. We instead do not assume individuals to solve this problem.[4]

2.2.1 Empirical results for the basic model

Table 2.3 presents the estimation results for the basic model with randomization. To allow for a preference for a certain column, we add dummies to the utility of each consumption path corresponding to the particular column corresponding to that consumption path. The choice of the first column serves as a reference category.

Table 2.3 shows that the first and third column are most likely to be chosen, as was also suggested by Table 2.2. Although the column dummies are statistically significant it is worth mentioning that their magnitude is much less than when estimated on the 1998 data. There we find for instance that the dummy for the middle column is equal to 1.86 with a t-value of 6.39. Thus the randomization has wiped out most of the column effects, but not all of it. Although not significant at the 5% level, the estimated value of

[3] In the calculation of standard errors we correct for the fact that the four choices of a respondent may be correlated due to unobserved heterogeneity.

[4] In fact it is not clear what meaning to attach to an Euler equation, as the respondents only get to choose from a discrete number of consumption paths. There is no reason to assume that the best choice out of this limited number satisfies first order equations, not in the least because the respondent is not even informed about the parameters of the budget constraint, like the interest rate.

Table 2.3: *Preference parameters for consumption paths (basic model)*

Parameters	Coeff.	s.e.	t-value
delta	-.094	.051	1.84
ln(rho)	.664	.122	5.46
Dummy for column 2	-.128	.044	2.89
Dummy for column 3	.010	.044	.23
Dummy for column 4	-.135	.044	3.04
Dummy for column 5	-.100	.044	2.30
Log likelihood	-9928.4		

δ $(-.094)$ is in line with the findings of BJKS, who find a preference for upward sloping consumption paths. The estimated value of ρ (exp(.664) $= 1.94$) is smaller than usually found in the literature. The implied IES $\frac{1}{\rho} = .51$ is larger than usually found. For instance, BJKS (who use the individual data to derive bounds on individual parameters) report an average upper bound on the IES equal to 0.36. Hall (1988) using a revealed preference representative agent approach estimates the IES to be around .1. We return to this below, when we consider more complicated models.

2.2.2 Parameterization of δ and ρ

We allow for variation in preferences, by making both δ and ρ a function of observable characteristics. One should note that the influence of characteristics on the two parameters δ and ρ is probably not non-parametrically identified, so interpretation of the separate estimates has to be interpreted with care. As a reflection of the tenuous identification, we found that convergence was sometimes difficult to achieve if we included all observable characteristics in the equations for both parameters. Thus we were forced to impose rather arbitrary exclusion restrictions. The estimation results that yielded the highest likelihood value are given in Table 2.4. The improvement in the log-likelihood value as a result of the parameterization is considerable as one can see from a comparison of Tables 2.4 and 2.3. The parameters of age and age squared are jointly significant at the 1% level for both ρ and δ. The education dummies are jointly insignificant for δ. Gender does not have any significant impact on either ρ or δ. The effect of household income on δ is significant at the 5% level and suggests that patience rises with income, as also found by Lawrance (1991).

Table 2.4: *Preference parameters for consumption paths*

Parameter	Coeff.	s.e.	t-value
delta			
age	.339	.088	3.83
age squared	.006	.002	3.43
gender	-.013	.023	0.59
middle education	.001	.014	0.09
higher education	-.012	.011	1.11
log(household inc.)	-.050	.009	5.49
constant	5.121	1.35	3.78
ln(rho)			
age	-.030	.006	4.72
age squared	.001	.0004	3.11
gender	.019	.049	0.38
constant	.386	.123	3.14
Dummy for column 2	-.125	.044	2.83
Dummy for column 3	.010	.044	0.24
Dummy for column 4	-.135	.045	3.01
Dummy for column 5	-.100	.044	2.29
Log likelihood	-9879.9		

2.3 Habit Formation

We now relax the assumption of intertemporal additivity of the utility function, so that the marginal rate of substitution between any two periods is no longer independent of the level of consumption in any two other periods. Thus, we consider life time utility functions of the following form:

$$\overline{u} = \sum_{t=l}^{L} (1+\delta)^{l-t} v(c_t, z_t) \tag{2.12}$$

where, as before, L is the horizon, δ the discount rate, t denotes the time period, v is the intratemporal utility function, c_t is consumption in period t, and z_t now reflects the stock of habits.[5] To complete the model we have to describe the evolution of the stock of habits. We consider two alternative cases: First order Markov (AR) habits and Moving Average (MA) habits. The former is the simplest case, where we specify the intratemporal utility function as $v(h(c_t) - \theta h(z_t))$, $h(.)$ being a monotonically increasing function. In the MA case we let habits evolve according to $h(z_t) = \beta h(z_{t-1}) + (1-\beta) h(c_{t-1})$,with $0 < \beta < 1$. In the remainder we choose the logarithm for the function $h(.)$. In contrast to the previous case, habits now have an infinite memory. The detailed derivation of the utility function for both specifications are reported in Appendix A.

2.3.1 The intertemporal elasticity of substitution for the model with habit formation

The introduction of habit formation breaks the tight link between the coefficient of relative risk aversion and the intertemporal elasticity of substitution.[6] Below we present the IES for the model with moving average habit formation. This also covers the AR-case, as the AR-case is a special case of MA, obtained by setting $\beta = 0$. Our derivation closely follows Carroll (2000), who provides a derivation of the Euler equation with a slightly different specification of habit formation. The detailed derivation is reported in Appendix B. Here we only present the IES for the steady state. This turns out to be approximately equal to:

[5] Notice that in this context we only deal with rational habit formation (cf., e.g, Spinnewijn, 1981) as the respondents are assumed to consider the whole consumption path.

[6] Of course, habit formation is not the only way to break the link between risk aversion and intertemporal subsitution, cf. e.g., Epstein and Zin (1989, 1991).

$$\text{IES} \approx \frac{1}{\rho + \theta - \rho\theta} \tag{2.13}$$

2.3.2 Empirical results for the models with habit formation

We estimate AR and MA specifications, both with and without parameterization of the preference parameters. The estimation results for the AR and MA specifications without parameterization are reported in Tables 2.5 and 2.6, respectively. For all cases, the number of observations is 1545, as in the previous sections. In the specification of the stock of habits we face the problem that we do not know z_0. Somewhat arbitrarily we have set z_0 equal to .9 times household income. Experiments where the number .9 is replaced by respectively .95, .8, and .7 yield estimation results that are comparable to the results we present below.

The log-likelihood values are -9921.2 for the AR-specificationfor the AR-specification and -9894.1 and for the MA-specification. The estimates of ρ and δ are quite similar in both specifications. As in Table 2.3 we find a negative time preference rate, which is in line with the results of BJKS, but at variance with much of the literature discussed in the Introduction. The parameters θ and β are both between zero and one and significantly different from zero. These results indicate that (rational) habits play an important role in the choice of consumption paths. The most striking difference between the results presented in Tables 2.5 and 2.6 and the results presented in Table 2.3 (the specification without habit formation) lies in the value of ρ. The estimates in Tables 2.5 and 2.6 imply much more curvature than the estimate from Table 2.3. The steady state IES implied by Table 2.5 is .57, whereas the steady state IES implied by Table 2.6 is equal to .53. These values are about equal to the estimate of the IES implied by the estimate of ρ in Table 2.3 (.51). Thus we find that the value of the IES is quite robust with respect to the specification of habit formation. But the curvature of the utility function implied by the estimate of ρ is much larger in the specification with habit formation than without.

As before, we have parameterized the parameters of interest (δ, $\ln\rho$, θ, and β) by making them dependent on respondent characteristics. Since, as noted above, identification of the effects of background variables on the parameters is only identified by functional form we abstain from presenting the myriad of parameter estimates. We only note that the log-likelihood for the AR model with parameterization increases to -9775.2, which is to be compared to the log-likelihood value in Table 2.5 (-9921.2). Attempts to also parameterize the MA-model lead to a likelihood that is slightly higher, but convergence

Table 2.5: *AR-specification*

Parameters	Coeff.	s.e.	t-value
delta	-.100	.062	1.61
ln(rho)	1.57	.239	6.54
theta	.801	.021	37.24
Dummy for column 2	-.128	.044	2.89
Dummy for column 3	.010	.044	0.22
Dummy for column 4	-.135	.044	3.03
Dummy for column 5	-.102	.044	2.33
log-likelihood	-9921.2		

Table 2.6: *MA-specification*

Parameters	Coeff.	s.e.	t-value
delta	-.110	.026	4.25
ln(rho)	1.60	.091	17.57
theta	.777	.018	42.11
beta	.929	.007	123.2
Dummy for column 2	-.127	.044	2.88
Dummy for column 3	.010	.044	0.22
Dummy for column 4	-.134	.045	3.01
Dummy for column 5	-.101	.044	2.31
log-likelihood	-9894.2		

appeared hard to achieve. The latter indicates that making the four different parameters dependent on the same background characteristics is more than the data can bear.

2.4 Concluding Remarks

Our analysis is based on information from direct questions about hypothetical intertemporal consumption choices. In comparison with revealed preference approaches, the use of direct questioning to elicit dynamic preferences over consumption has the advantage of simplicity and the avoidance of strong assumptions on the constraints faced by an individual. On the other hand of course, it is still a major step to incorporate the preferences we have elicited in a model of actual behaviour. As BJKS we find for instance that consumers are very patient (the time preference rate is negative) or equivalently that consumers prefer upward sloping consumption profiles. The fact that other studies appear to find large and positive time preference rates may indicate that self-control is a major problem in actual behaviour. With some exceptions, self-control is still not modelled extensively in economic models of intertemporal choice.

It is of interest to note that the estimate of the IES appears to be quite robust with respect to the different assumptions regarding habit formation. The coefficient of relative risk aversion however changes substantially across specifications. In itself this demonstrates the importance of breaking the connection between IES and risk aversion in intertemporal models. The main finding of our empirical analysis may be the rejection of intertemporal additivity.

The set-up of the questionnaire can be further improved. The way the consumption paths have been presented by giving consumption levels at specified ages potentially leads to ambiguity. A better way to present consumption paths may be to show full graphs to respondents, or to assign all respondents the same horizon of ten years (say). We could then also systematically vary the horizon and investigate the effect of this on the elicited choices. These are experiments left for future work.

Chapter 3

Subjective Measures of Risk Aversion and Portfolio Choice

3.1 Introduction

This chapter exploits direct measures of risk preferences in a model of household portfolio allocation. There are two main motivations for this. The first one is that if heterogeneity in risk preferences is important then empirical portfolio models should take this into account. The second motivation is that economic theory has a fair amount to say about how risk preferences should influence portfolio allocation. Having direct measures of risk preferences should therefore help us in better testing the validity or predictive power of economic theories of portfolio allocation.

Empirical analyses of portfolio choice of households or individuals appear to indicate that observed choices are often inconsistent with standard asset allocation models. As a consequence, several studies have focused on empirical failures of portfolio theory. The greatest failure is perhaps the fact that the majority of individuals do not hold fully diversified portfolios, although the percentage of households holding risky assets has increased over the last decade (Haliassos and Hassapis, 2000). A potential explanation for the fact that many households do not hold stocks may be lie in the costs of stock market participation (Vissing-Jorgensen, 2000).

The sub-optimal degree of international diversification known as "home asset bias" is potentially another empirical failure. It has been analyzed, among others, by French and Poterba (1990, 1991), Tesar and Werner (1992, 1994, 1995), Cooper and Kaplanis (1994), Glassman and Riddick (2001), and Jermann(2002). Possible reasons for the over-investment in domestic assets have been identified in different transaction costs between countries, additional sources of risk for foreign investments and explicit omission of assets from the investor's opportunity set.

A more fundamental piece of evidence against the rational model of portfolio allocation is provided by Benartzi and Thaler (2001) who find that the allocation of investors is heavily dependent upon the choices offered to them. Roughly speaking, if they are offered n choices they tend to allocate $\frac{1}{n}$ of their investment to each of the choices offered, independent of the risk characteristics of the investment opportunities.

Although these findings suggest that the rational model of choice is unable to explain several empirical phenomena, it is often hard to determine in more detail what the underlying cause of disparities between theory and empirical facts may be. The connection between theory and empirical evidence is often tenuous, because too many intervening factors may explain why theoretical predictions are not borne out by data. For this reason some authors have turned to more direct, subjective evidence on preferences to reduce the distance between theory and empirical facts. A prominent example is the paper by Barsky et al. (1997) who elicit several pieces of subjective information to improve our understanding of intertemporal choice and portfolio allocation.

In this chapter we also aim to exploit subjective information to construct empirical micro-models of portfolio choice. In contrast with the work by Barsky et al. (1997) and Arrondel (2000), our model will be a formal structural model of portfolio choice, in which we consider several different measures of risk attitude. One measure is based on hypothetical choices between uncertain income streams in a household survey, and closely related to the aforementioned work by Barsky et al. (1997) and Arrondel (2000). The Barsky et al. measure has a nice direct interpretation if individuals have CRRA preferences. We will find however, that the measure also has theoretical and empirical problems. Hence we also consider alternative measures of risk attitude. We relate the different measured risk attitudes to observed portfolio choices of households. To deal with incomplete portfolios, we set up a simple rationing model that can endogenously generate corner solutions in portfolio allocation. Thus, we formulate and estimate a complete system of portfolio demand equations incorporating subjective measures of risk aversion. The model is closely related to rational portfolio theory and seems to do a reasonable job in describing differences in allocation across individuals who differ in socio-economic characteristics, wealth, and risk attitudes.

The chapter is organized as follows. In the next Section 3.2 we describe the data we use in the analysis. In particular we present descriptive statistics on the various risk attitude measures and on the portfolio composition of households. Section 3.3 discusses some results from the literature regarding the classical theory of portfolio choice. Based on these results we formulate in Section 3.4 a simple static asset allocation model with rationing. The rationing emerges as the result of corner solutions (i.e. the existence of incomplete portfolios). We then derive an econometric model with switching regimes, where each regime is characterized by a particular asset ownership pattern. The model has two components: the first component determines the regime, and the second component describes portfolio shares of assets conditional on the regime. Section 3.5 presents empirical results and Section 3.6 concludes the chapter.

3.2 Data on risk aversion and precaution and how they were collected

The data used in this chapter have been collected from the households in the so-called CentERpanel. The CentERpanel is representative of the Dutch population, comprising some 2000 households in the Netherlands. The members of those households answer a questionnaire at their home computers every week. These computers may either be their own computer or a PC provided by CentERdata, the agency running the panel[1]. In the weekends of August 7-10 and August 14-17 of 1998 a questionnaire was fielded with a large number of subjective questions on hypothetical choices. The questionnaire was repeated in the weekends of November 20-23 and November 27-30 of 1998 for those panel members who had not responded yet. For this chapter we exploit the section involving choices over uncertain lifetime incomes. We merge these data with data from the CentER Savings Survey (CSS). The CSS collects data on assets, liabilities, demographics, work, housing, mortgages, health and income, and many subjective variables (e.g. expectations, savings motives) from annual interviews with participants in the CentERpanel. Typically the questions for the CSS are asked in May of each year, during a number of consecutive weekends.

We discuss consecutively three measures of risk aversion elicited from the respondents in the sample.

3.2.1 Choices of uncertain lifetime income

Our first measure is based on a number of questions involving risky choices over lifetime incomes. This methodology, taken from Barsky et al. (1997) (BJKS, from now on), allows us to rank individuals with respect to their risk aversion without having to assume a particular functional form for the utility function.

In the BJKS experiment, questions are posed to all respondents, consisting of individuals aged over 50. Arrondel (2000) asked the questions to a representative sample of French households. In our case, the questions are asked only to people who have a job *and* who are the main breadwinner in a household (i.e. the person in the household who brings in the largest amount of money).

[1] The description refers to the time of the survey. Nowadays, CentERdata does not provide a PC any longer but a set-top box.

The structure of the questions is depicted in Figure 3.1. In the first round, respondents are asked the following question:

Imagine your doctor recommends that you move because of allergies. You follow his advice, and it turns out you have to choose between two possible jobs. Both jobs are about equally demanding (for example, both jobs involve the same number of working hours per week), but the income in one job is much more certain than the income in the other job.

The first job guarantees your current income for the rest of your life. In addition, we assume that income other members of your household may have, will also remain unchanged. In this situation, you know for sure that during the remainder of your life, the net income of your household will be equal to Dfl. Y.

The second job is possibly better paying, but the income is also less certain. In this job, there is a 50% chance that you will earn so much that the income of your household will be doubled for the rest of your life, that is, be equal to Dfl. $Yx2$.

There is, however, an equally big chance (50%) that you will earn substantially less in the second job. In the latter case, the net monthly income of your household will for the rest of your life be equal to Dfl. $Yx07$.

Which job would you take?

1 the job with the guaranteed fixed household income of Dfl. Y

2 the job that involves a 50% chance that the income of your household will for the rest of your life be equal to Dfl. $Yx2$*, but also involves a 50% chance that the income of your household will for the rest of your life be equal to* $Yx07$.

Various quantities in the question vary per respondent, exploiting the computerized nature of the interviews. The quantity Y is the respondent's selfreported after tax household income. Yx2 is twice the household income; Yx07 is household income times .7, etc. This is in contrast to the experiments by BJKS and Arrondel (2000), in which the incomes were the same for all individuals. Obviously, the question involves a choice between a certain and an uncertain outcome: the former is given by the actual income the respondent receives (Y), the latter is a 50-50 gamble over a good outcome (Yx2) and a bad outcome (Yx*07*).

In the second round each individual is asked a similar question. If she has chosen the certain outcome (Y) in the first round, she now faces another gamble where the risky outcome is more attractive. The 50-50 gamble now involves Yx2 and Yx08 (.8 times income). If she has chosen the risky prospect in the first round, she is now asked to choose between her income for sure and a less attractive gamble, i.e. 50% chance of Yx2 and 50% chance of Yx05.

Similarly, in the third round the gamble becomes more attractive for those respondents who have once again chosen a certain income stream in the second round (the 50-50 gamble now involves Yx2 and Yx09), and less attractive for those respondents who preferred the risky choice (the 50-50 gamble now involves Yx2 and Yx025)

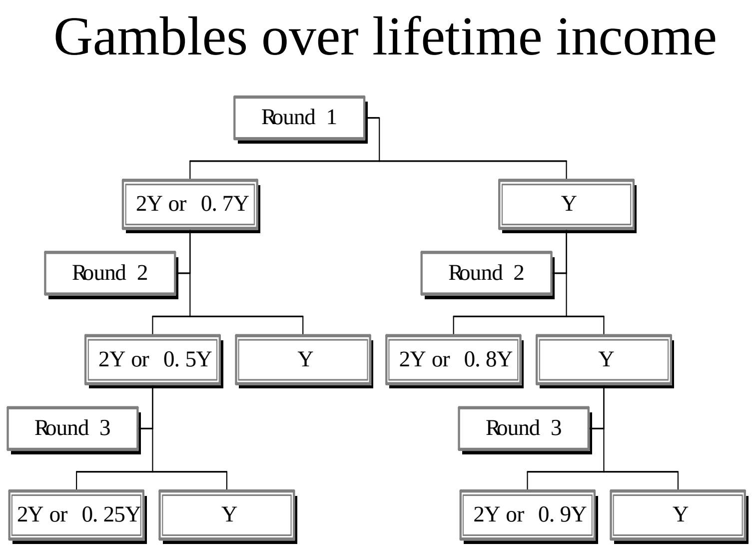

Figure 3.1: Choices of uncertain lifetime income

The answers to the questions allow us to identify six groups ranked from most risk averse to least risk averse (or equivalently from least risk tolerant to most risk tolerant; we will generally denote the variable defined by the six classes as "risk tolerance"). Both the BJKS study and Arrondel's involve only two rounds of questions rather than three as ours. For comparison we temporarily combine the two most extreme groups into one. Thus we have four categories of individuals, from I to IV, where the I-group is the union of the 1 and the 2 groups and the IV-group is the union of the 5 and 6 groups. We can then compare the risk tolerance across the three studies. Table 3.1 gives the results. To facilitate a comparison with the BJKS study we split our sample in two age groups: 50

and younger and over 50[2].

An unfortunate aspect of the sample selection (respondents being employed and being the main breadwinner) is that it severely limits the number of observations. This clearly reduces the possibility of obtaining statistically significant results. Keeping this in mind, a comparison between France and The Netherlands on the basis of the complete age range suggests that there is a greater spread of risk aversion in The Netherlands than in France. The Dutch respondents are more heavily represented in the two extreme categories (almost 53% of the Dutch belong to the most risk averse group compared to 43% of the French, whereas 12% of the Dutch belong to the least risk averse group compared to 6% for the French). Summing the percentages of the first two groups and the percentages of the last two groups respectively, suggests that the Dutch are less risk averse than the French (only 69.5% of the Dutch belong to the first two groups compared to 82.5% of the French, whereas 30.5% of the Dutch belong to the last two groups compared to 17.5% of the French).

Considering the subsamples of respondents over 50, it appears that the Dutch have similar risk preferences to the Americans, although the Americans may be slightly more risk tolerant than the Dutch. Compared to the Dutch and the Americans, the French appear to be much more risk averse.

Table 3.1: *Risk Tolerance in the USA, France and The Netherlands*

	Total sample		Respondents over 50		
Group	**France**	**Neth.**	**USA**	**France**	**Neth.**
I	43.1	52.8	64.6	48.6	66.3
II	39.4	16.7	11.6	36.8	13.5
III	11.2	18.1	10.9	8.7	9.0
IV	6.3	12.4	12.8	5.9	11.2
Total	100	100	100	100	100
Obs.	2954	657	11707	2954	178

[2] The BJKS sample consists of respondents over 50.

Turning to a closer analysis of the Dutch data, we once again distinguish six classes of risk tolerance. Table 3.2 presents a number of descriptive statistics of the risk tolerance variable by several demographic and socio-economic characteristics. For the purpose of this table, the risk tolerance has been coded from 1 (least risk tolerant) to 6 (most risk tolerant). The p-values refer to one way analyses of variance of each of the risk attitude measures on the characteristics considered. Notice that there is a very uneven distribution of males and females in the sample. This is the result of the fact that only employed main breadwinners have been selected. The vast majority of the respondents fall in the most risk averse categories. Although the table might suggest that females are more risk averse than males, the difference in means is small and clearly not significant. Table 3.2 suggests that better educated individuals are generally less risk averse; the differences in risk tolerance between the three levels of education are statistically significant. Although the table suggests that the self-employed are substantially more risk tolerant than employees, the small number of observations of self-employed respondents leads to statistically insignificant differences.

Table 3.2: *Risk attitude variable by background characteristics (means)*

Characteristic	**Risk tolerance**	**N.obs.**
Male	2.724	567
Female	2.555	90
p-value	*.32*	
Low education	2.345	259
Middle education	2.882	212
High education	2.796	266
p-value	.001	
Employees	2.68	622
Self-employed	3.085	35
p-value	*.12*	
Whole sample	2.701	657

3.2.2 Risk attitude measures based on principal components

The CSS-questionnaire contains six direct questions about investment strategies. These are reproduced below. Respondents can express their agreement or disagreement with these statements on a seven point scale (1 means complete disagreement and 7 means complete agreement.

SPAAR1

I find it more important to invest safely and to get a guaranteed return than to take risks in order to possibly get a higher return.

SPAAR2

Investing in stocks is something I don't do, since it is too risky.

SPAAR3

If I believe an investment will carry a profit, I am willing to borrow money for it.

SPAAR4

I want to be sure my investments are safe

SPAAR5

I am increasingly convinced that I need to take more financial risks if I want to improve my financial position.

SPAAR6

I am willing to run the risk of loosing money if there is also a chance that I will make money.

The CSS also contains 13 questions about savings motives. Below we reproduce three of them that are related to precautionary motives and uncertainty. Answers can be given on a 1 to 7 scale, where 1 means "very unimportant" and 7 means "very important".

SPAARM03

To have some savings in case of unforeseen expenses due to illness or an accident.

SPAARM12

As a reserve for unforeseen events

SPAARM13

To have enough money in the bank, so that I can be sure to be able to meet my financial obligations.

Applying principal components analysis to these nine indicators of risk aversion and precaution, we find that three underlying factors can explain most of the variance in the answers. After applying varimax rotation we find the factor loadings presented in

Table 3.3. The largest factor loadings in each column are given in bold face. We note that the factors which we have called “riskat1” and “riskat3” mainly explain the six ”spaar” variables, whereas “riskat2” mainly explains the “spaarm” variables. In view of the wordings of the nine questions, we interpret riskat1 and riskat3 as measures of risk aversion, whereas riskat2 is mainly a measure of prudence. Thus we would expect riskat2 to play a role in savings decisions whereas riskat1 and riskat3 should affect portfolio choice.

Table 3.3: *Rotated factor loadings (varimax rotation)*

Variables	**riskat1**	**riskat2**	**riskat3**	**uniqueness**
spaarm03	-0.038	**0.796**	-0.017	0.365
spaarm12	0.163	**0.838**	0.023	0.270
spaarm13	0.154	**0.785**	0.036	0.360
spaar1	**0.838**	0.111	0.058	0.282
spaar2	**0.632**	-0.007	0.370	0.464
spaar3	0.006	0.030	**0.724**	0.475
spaar4	**0.817**	0.151	0.046	0.307
spaar5	-0.015	0.037	**0.785**	0.382
spaar6	0.346	-0.027	**0.758**	0.304

Table 3.4 presents a number of descriptive statistics of the three risk attitude measures by several demographic and socio-economic characteristics, organized in a similar way as Table 3.2. The risk attitude measures are normalized such that they have zero mean and unit variance for the complete sample. The variance varies slightly across subgroups but usually very little. Table 3.4 shows that all three risk attitude measures are significantly less for males than for females, implying that males are less risk averse and have a less strong precautionary motive. Education only has a significant effect for riskat1, with a pattern that is hard to interpret. Despite the small number of self-employed in our sample we do find significant less risk aversion (or precaution) among the self-employed than among employees for riskat2 and riskat3. For riskat1, the difference is not significant.

Table 3.4: *Risk attitude variables by background characteristics (means)*

Characteristic	**riskat1**	**riskat2**	**riskat3**	**N.obs.**
Male	-.071	-.092	-.126	529
Female	.123	.159	.219	304
p-value	*.007*	*.0005*	*.0000*	
Low education	.032	.087	.060	259
Middle education	.075	-.007	-.048	255
High education	-.119	-.066	-.026	283
p-value	*.06*	*.21*	*.422*	
Employees	-.098	.039	-.092	407
Self-employed	.259	-.356	-.575	21
p-value	*.13*	*.07*	*.03*	
Whole sample	-1.85e-09	9.98e-10	4.42e-10	833

3.2.3 Direct questions on precaution and risk aversion

The third type of subjective measures are the answers to the following two questions, which were included in the same module of the CentERpanel as the BJKS risk aversion measure. The questions read as follows:

Would you rather describe yourself as a carefree person, or rather as a careful person?
When there is possible danger, do you take many precautions?

Responses in both cases could be given on a seven point scale. We will refer to the first variable as "careful" and to the second variable as "precaution". Table 3.5 presents a number of descriptive statistics of the two risk attitude measures by several demographic and socio-economic characteristics, analogous to Tables 3.2 and 3.4 above. The table contains the mean scores on the seven point scales for both variables. We observe that females are significantly more "careful" than males. Both careful and precaution appear negatively related with education.

Table 3.5: *Risk attitude variables by background characteristics (means)*

Characteristic	**careful**	**precaution**	**N.obs.**
Male	5.001	4.843	977
Female	5.110	4.896	734
p-value	*.04*	*.44*	
Low education	5.096	4.948	560
Middle education	5.048	4.877	531
High education	5.003	4.764	523
p-value	*.001*	*.04*	
Employees	4.916	4.711	786
Self-employed	4.914	4.851	47
p-value	*.90*	*.31*	
Whole sample	5.047	4.866	1711

3.2.4 How are the subjective measures related?

Before turning to the analysis of the relation between the various measures of risk tolerance and portfolio composition we present analyses of the interrelation between the various measures. First of all, comparing the outcomes presented in Tables 3.2, 3.4, and 3.5, we notice the following patterns. Splitting the sample by gender, risk tolerance does not reveal significant differences, but riskat1, riskat2, riskat3, and careful all indicate that males are more risk tolerant and less precautious than females. Distinguishing respondents by education shows that risk tolerance, riskat1, careful, and precaution all suggest that people with higher education are less risk averse and less precautious. Riskat2 and riskat3 do not differ significantly by education. Finally, only riskat2 and riskat3 differ significantly (at the 7% and 3% level respectively) between self-employed and employees. The lack of significant differences for the other variables does not necessarily mean that employees and self-employed do not differ, but may rather be a reflection of the small number of self-employed in the sample.

Table 3.6 presents results of regressing each of the measures on a number of background variables and the other measures. For the explanation of risk tolerance, careful and precaution the method of analysis is ordered probit. For riskat1 through riskat3 we use regression. The ordinal variables risk tolerance careful and precaution are simply coded from 1 to 7 when used as explanatory variables. Replacing the simple coding by dummies does not alter the outcomes appreciably. Since the variables do not all come from the same interview and because not all questions are asked to all respondents, the number of observations is fairly small, reflecting the partial overlap in observations. Of course, the regressions should be viewed as purely descriptive. They present a way of showing the nature of the interrelations between the six measures. Although we briefly discuss the effects of background variables, like age, income, wealth, gender, education, and being self-employed, one should keep in mind that the effects of these variables are all conditional on all the other risk attitude measures in the regressions.

Age is only significant for risk tolerance and riskat1. Figure 3.2 draws the quadratic age functions implied by the estimates for all six measures. The figure shows that both risk tolerance and riskat1 imply that risk aversion increases with age. The variables income and total wealth are both coded in the form of an inverse hyperbolic sine[3]. Income has a significant effect on risk tolerance and riskat1. The signs of the effects imply in both cases decreasing risk aversion with income. Wealth is (marginally) significant in four out of six regressions. The estimation results for risk tolerance suggest increasing relative risk aversion with increasing wealth, which would be consistent with a constant absolute risk aversion utility function, for instance. The results for riskat3 suggest decreasing risk aversion with increasing wealth, but since we do not know how riskat3 would be related exactly to the parameters of a known utility function, the result is hard to interpret. The two precautionary measures (precaution and riskat2) increase with wealth. Gender is never significant and education and being self-employed are only significant for risk tolerance. One should recall once again, that these effects are to be interpreted as being conditional on the other risk attitude measures.

Turning to the interrelationships between the risk attitude measures, we observe that precaution and riskat2 appear to be significantly related, as one would expect from the interpretation of riskat2. Somewhat less expected, careful, riskat3, and risk tolerance are also significantly related to precaution.

[3] The inverse hyperbolix sine of x is $h(x) = \ln[1 + \sqrt{x^2 + 1}]$

Table 3.6: *Interrelationships between the various measures (ordered probit and ols estimates)*

Expl. variables	**Risk tol.**	**Careful**	**Precau.**	**Riskat1**	**Riskat2**	**Riskat3**
Age	.046	.100	-.052	.051	-.090	.026
Age squared	-.0008	-.001	.0005	-.0004	.001	-.0003
p-value age eff.	*.002*	*.133*	*.423*	*.050*	*.186*	*.864*
Income	.533	-.321	.206	-.503	-.110	.004
t-value	*2.79*	*1.67*	*1.09*	*2.91*	*.65*	*.02*
wealth	-.070	.125	-.052	.036	.065	-.075
t-value	*1.90*	*3.37*	*1.39*	*1.05*	*1.94*	*2.27*
Gender	-.047	-.072	-.168	-.072	.379	.204
t-value	*.26*	*.40*	*.93*	*.44*	*2.34*	*1.28*
Self-empl.	.624	-.008	.186	.238	-..497	-.246
t-value	*2.12*	*.03*	*.62*	*.87*	*1.85*	*.93*
Middle educ.	.435	-.131	.164	.067	-.174	.108
High educ.	.331	-.125	.175	.042	-.278	.071
p-value ed eff.	*.023*	*.676*	*.492*	*.901*	*.149*	*.745*
Careful	-.058	-	.531	.189	.055	-.044
t-value	*1.00*	-	*9.72*	*3.63*	*1.09*	*.87*
Precaution	-.152	.518	-	-.013	.102	.103
t-value	*2.69*	*9.62*	-	*.26*	*2.02*	*2.07*
Risk tolerance	-	-.049	-.127	-.113	.058	-.067
t-value	-	*1.09*	*2.85*	*2.77*	*1.44*	*1.71*
Riskat1	-.172	.233	-.009	-	-	-
t-value	*2.90*	*3.90*	*.15*	-	-	-
Riskat2	.083	.086	.134	-	-	-
t-value	*1.33*	*1.40*	*2.20*	-	-	-
Riskat3	-.120	-.021	.130	-	-	-
t-value	*1.94*	*.33*	*2.10*	-	-	-
Number of obs.	342	342	342	342	342	342
(Pseudo) R^2	0.066	.156	.128	.158	.076	.060

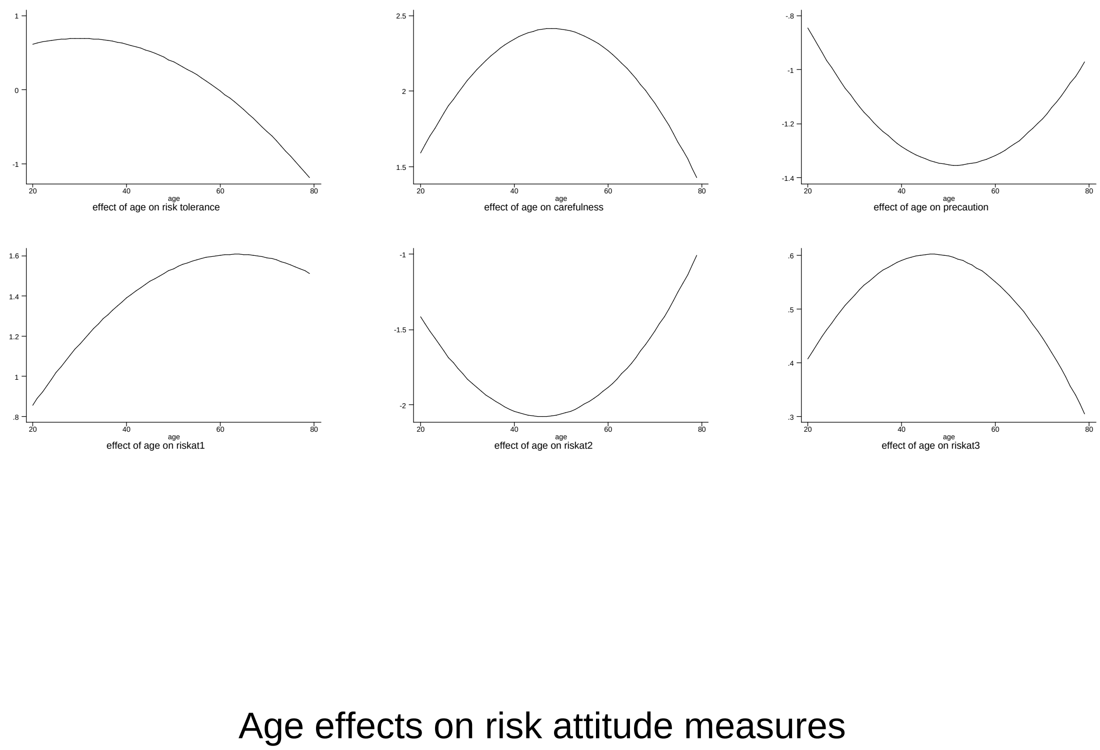

Figure 3.2: Age functions for the six risk attitude measures

3.2.5 Assets and liabilities

The CSS collects extensive information on assets and liabilities. Respondents are asked for ownership and quantity of different categories of assets, both real and financial, and of liabilities and mortgages. Table 3.7 reports data on financial assets at the household level. We group assets in categories that are somewhat homogeneous with respect to their risk profile. We have indicated the category an asset belongs to by NR for non-risky assets, by R for risky assets and by O for "other" assets. Non-risky assets are checking accounts, savings accounts, deposits, and insurances. Risky assets are defined as the sum of growth and mutual funds, options, stocks and business equity. Other assets are the sum of real estate, mortgage, bonds, money lent out and financial debt. The table presents relative frequencies of ownership, mean values and shares of each asset category in the total portfolio. Notice that the data do not only refer to the respondents who have been posed the questions about uncertain life time incomes.

Checking accounts, savings accounts, deposits, and insurances are held by 96.3% of the sample. This safe asset makes up close to 50% of average financial wealth in the sample. Business equity is another sizeable component of financial wealth, although it is only held by 7.1% of the sample. Generally, the households in the sample use very little credit: Financial debts amount to less than 10% of total financial assets (and hence financial wealth is more than 90% of total financial assets). Only 4.5% of the sample holds bonds and/or mortgage bonds, whereas 16.5% holds stocks; 22.6% of the sample holds growth or mutual funds. Of course the group of stock holders overlaps with the owners of mutual funds or growth funds. 30.4% of the sample households have stocks and/or growth and mutual funds. Clearly, for most households real estate (usually the primary residence) dominates the portfolio. Financial assets are only 27% of total assets and financial wealth is only 33% of total wealth.

At the aggregate level, both risky and non-risky assets are basically 50% of average financial wealth, but the percentage of people owning risky assets (34.5) is far less than half of that of people owning safe assets (96.3). Other assets are widely spread over the sample (82.8%) and they are 175.9% of financial assets.

Table 3.7: *Households' assets and liabilities in 1998*

Assets	Type	Obs.	% own	Mean	% f.ass.	% t. ass.
Checking, dep., ins., etc.	*NR*	1427	96.3	45630	48.7	13.2
Growth, mutual funds	*R*	1427	22.6	11603	12.3	3.3
Bonds	*O*	1427	4.5	2187	2.3	.6
Stocks	*R*	1427	16.5	15683	16.7	4.5
Options	*R*	1427	1.1	115	.1	.03
Money lent out	*O*	1427	8.3	1943	2.1	.6
Business equity	*O*	1427	7.1	16591	17.7	4.8
Total financial assets		1427	-	93753	100	27.0
Real estate	*O*	1422	68.0	252650	-	72.9
Total assets		1422	-	346693	-	100
Financial debt	*O*	1427	-	8976	9.6	2.6
Mortgage	*O*	1422	55.8	82952	-	23.9
Net financial wealth		1427	-	84776	90.4	24.4
Non-risky assets	*NR*	1427	96.3	45630	48.7	13.2
Risky assets	*R*	1427	34.5	43992	46.9	12.7
Other assets	*O*	1422	82.8	346456	175.9	47.6
Net worth		1422	-	254803	-	73.5

NR: non-risky; *R*: risky; *O*: other assets. All amounts are in Dutch guilders (about \$.50 in 1998)

3.3 Some theory

To motivate our empirical model, it is useful to summarize some concepts and results from the literature. In the exposition below we mainly follow the excellent new book by Gollier (2002).

3.3.1 Comparative risk aversion

Agent 1 is more risk averse than agent 2 if

$$E[u_2(w_0 + \widetilde{x}) \leq u_2(w_0) \Rightarrow E[u_1(w_0 + \widetilde{x}) \leq u_1(w_0)] \tag{3.1}$$

where u_2 and u_1 are utility functions, w_0 is initial wealth and $\widetilde{x}$ is a risky asset with zero expected return. This is equivalent with $A_1(w_0) \geq A_2(w_0)$, where $A_i(z) \equiv -\frac{u''(z)}{u'(z)}$, the coefficient of absolute risk aversion. Of course, if the coefficient of absolute risk aversion is larger for individual 1 at some positive wealth level z, then this is also true of the coefficient of relative risk aversion: $R_i(z) = z.A_i(z)$...

3.3.2 HARA (harmonic absolute risk aversion) utility functions

$$u(z) = \zeta(\eta + \frac{z}{\gamma})^{1-\gamma} \tag{3.2}$$

Absolute risk tolerance (the inverse of absolute risk aversion) for this utility function is equal to

$$T(z) = \frac{1}{A(z)} = -\frac{u''(z)}{u'(z)} = \eta + \frac{z}{\gamma} \tag{3.3}$$

Thus, absolute risk tolerance (inverse absolute risk aversion) is linear in wealth, which explains the name of this class of utility functions. Notice that the coefficient of relative risk aversion then equals

$$R(z) = \frac{z}{\eta + \frac{z}{\gamma}} \tag{3.4}$$

and the degree of absolute prudence:

$$P(z) = -\frac{u'''(z)}{u''(z)} = \frac{\gamma + 1}{\gamma}(\eta + \frac{z}{\gamma})^{-1} \tag{3.5}$$

The degree of relative prudence is $zP(z)$.

Notice that if $\eta = 0$, the utility function reduces to

$$u(z) = \zeta(\frac{z}{\gamma})^{1-\gamma} \tag{3.6}$$

which is the CRRA utility function with coefficient of relative risk aversion γ (cf. (3.4)). Similarly, if $\gamma \to \infty$, it can be shown that the utility function reduces to:

$$u(z) = -\frac{\exp(-Az)}{A} \tag{3.7}$$

where A is the coefficient of absolute risk aversion ($A = \frac{1}{\eta}$). Finally, for $\gamma = -1$, we obtain a quadratic utility function.

3.3.3 Risk aversion and portfolio choice

For CARA preferences (see (3.7)) the share of wealth to invest in a risky asset is

$$\frac{\alpha^*}{w_0} = \frac{\mu}{\sigma^2}\frac{1}{w_0 A} = \frac{\mu}{\sigma^2}\frac{1}{R(w_0)} \tag{3.8}$$

where μ and σ^2 are the mean and variance of the distribution of the excess return of the risky asset and α^* is the amount invested in the risky asset. For non-CARA preferences formula (3.8) is approximate.

HARA preferences (see (3.2)): For this case no explicit solution is available, but a numerical solution can be found in a rather simple way. Let a be the solution of the equation

$$E\widetilde{x}(1+\frac{a\widetilde{x}}{\gamma})^{-\gamma} = 0$$

then the general solution for α^* is equal to

$$\alpha^* = a(\eta + \frac{w_0}{\gamma}) = aT(w_0) \tag{3.9}$$

using (3.3). So we see that the **amount** invested in the risky asset is directly proportional to the degree of absolute risk tolerance. The **share** of total wealth invested in the risky asset is then inversely proportional to the degree of relative risk aversion. This is qualitatively similar to the result for CARA-preferences.

Next we consider the case of a vector of risky assets. We will restrict ourselves to CARA-preferences. To motivate the econometric model to be used in the sequel, we provide the derivation of the optimal portfolio for this case. Let μ be the $(k-1)$-vector of mean excess returns and Σ the variance covariance matrix of the excess returns. Let W be begin of period wealth, r is the riskfree interest rate. The $(k-1)$-vector α denotes the quantities invested in the risky assets, with stochastic returns given by the vector $\widetilde{x}_0$. Let ι be a $(k-1)$-vector of ones. Then $\iota'\alpha$ is the amount of money invested in the risky assets and $W - \iota'\alpha$ is the amount invested in the riskfree asset (No non-negativity restrictions are imposed). Consumption z is equal to the value of the assets at the end of the period. Thus consumption is:

$$z = (W - \iota'\alpha)(1+r) + \alpha'(\iota + \widetilde{x}_0) = W(1+r) + \alpha'(\widetilde{x}_0 - r) \equiv w_0 + \alpha'\widetilde{x} \tag{3.10}$$

where $w_0 = W(1+r)$ and $\widetilde{x} = \widetilde{x}_o - r.\iota$ ..We assume $\widetilde{x}$ to be normally distributed, so that $\widetilde{x} \sim N(\mu, \Sigma)$. The consumer wants to maximize the expectation of end of period utility subject to (3.10) by choosing α optimally. Inserting (3.10) in (3.7), neglecting the multiplicative constant A, and taking expectations yields

$$\begin{aligned} V(\alpha) &= -(2\pi)^{-n/2}\,|\Sigma|^{-1/2}\int \exp(-A(w_0+\alpha' x))\exp(-\frac{1}{2}(x-\mu)'\Sigma^{-1}(x-\mu))dx \\ &= \exp(-Aw_0 - A\alpha'\mu + \frac{1}{2}A^2\alpha'\Sigma\alpha).(2\pi)^{-n/2}\,|\Sigma|^{-1/2} \\ &\quad .\int \exp[-\frac{1}{2}(x-\mu+A\Sigma\alpha)'\Sigma^{-1}(x-\mu+A\Sigma\alpha)]dx \\ &= -\exp(-Aw_0 - A\alpha'\mu + \frac{1}{2}A^2\alpha'\Sigma\alpha) \qquad (3.11) \end{aligned}$$

Maximizing (3.11) with respect to α yields:

$$\alpha^* = \frac{1}{A}\Sigma^{-1}\mu \qquad (3.12)$$

We can also write this in terms of portfolio shares. In that case (3.8) generalizes to:

$$w = \Sigma^{-1}\mu.\frac{1}{R(w_0)} \qquad (3.13)$$

3.4 An econometric model of portfolio choice

Our interest will be in ownership and portfolio shares of a number of asset categories that vary in riskiness. We want to allow for other factors determining portfolio composition than just the distribution of excess returns. To introduce these other factors in a utility consistent way, we replace (3.11) by

$$V^*(\alpha) = -\exp(-Aw_0 - A\alpha'\mu - A^2 w_0\alpha'\Sigma z + \frac{1}{2}A^2\alpha'\Sigma\alpha) \qquad (3.14)$$

where z is a vector of taste shifters:

$$z = \Lambda x + \varepsilon \qquad (3.15)$$

where x is a vector of individual (or household) characteristics, Λ is a parameter matrix, and ϵ an i.i.d. error term. We will interpret ϵ as representing unobservable variations in taste across individuals.

Maximizing (3.14) with respect to the quantity vector α yields the following expression for the vector of risky asset shares:

$$\widetilde{w} = z + \frac{1}{R}\Sigma^{-1}\mu \equiv z + \Gamma\mu^* \qquad (3.16)$$

where $\Gamma = \Sigma^{-1}$ and $\mu^* = \frac{1}{R}\mu$.

Notice that no sign restrictions are imposed on the elements of $\widetilde{w}$. If we impose the condition that assets have to be non-negative -the empirically relevant case- the maximization of (3.14) has to take place subject to the condition $\alpha \geq 0$. Given that Γ is positive definite, necessary and sufficient conditions for a maximum are then:

$$\begin{aligned} \widetilde{\lambda} &\geq 0 \\ w &\geq 0 \\ \widetilde{\lambda}' w &= 0 \\ w &= z + \frac{1}{R}\Sigma^{-1}(\mu + \widetilde{\lambda}) = z + \Gamma(\mu^* + \lambda) \end{aligned} \tag{3.17}$$

where $\lambda = \widetilde{\lambda}/R$, and $\widetilde{\lambda}$ is a vector of Lagrange multipliers. The share of the riskless asset in the portfolio is equal to $1 - \iota_{k-1}' w$. Since the share of the riskless asset follows directly from the shares of the risky assets through adding up, we restrict our attention to the shares of the risky assets.

To characterize the Kuhn-Tucker conditions (3.17) it is convenient to define "virtual prices" $\widehat{\mu} \equiv \mu^* + \lambda$. It follows from the Kuhn-Tucker conditions that the virtual prices are equal to the corresponding elements of μ^* if the corresponding budget share is not equal to zero. To calculate virtual prices for the assets whose share equals zero, we introduce some notation. Let S' (k_1 x $(k-1)$) and D' (k_2 x $(k-1)$) be selection matrices with $k_1 + k_2 = k - 1$, i.e. $\begin{bmatrix} S' \\ D' \end{bmatrix}$ is a permutation of I_{k-1}, the $(k-1)$ x $(k-1)$ identity matrix. The matrix S' selects the elements of w which are zero and D' selects the elements of w which are non-zero. Some useful properties of S and D are:

$$S'S = I_{k_1} \quad D'D = I_{k_2} \quad SS' + DD' = I_{k-1} \quad D'S = 0 \tag{3.18}$$

Given that S' selects the elements of w that are zero, there holds $S'w = 0$, and similarly $D'\lambda = 0$.

The share equations in (3.17) can then be written as

$$\begin{bmatrix} 0 \\ D'w \end{bmatrix} = \begin{bmatrix} S' \\ D' \end{bmatrix} z + \begin{bmatrix} S' \\ D' \end{bmatrix} \Gamma[SS' + DD']\widehat{\mu} \tag{3.19}$$

The top-half of (3.19) gives as a solution for the virtual prices:

$$S'\widehat{\mu} = -(S'\Gamma S)^{-1}\{S'z + (S'\Gamma D)D'\mu^*\} \tag{3.20}$$

using the fact that $D'\widehat{\mu} = D'\mu^*$. Substituting this in the bottom half of (3.19) yields for the portfolio shares of the non-zero assets:

$$\begin{aligned} D'w &= D'z + \Pi S'z + (D'\Gamma D)D'\mu^* + \Pi(S'\Gamma D)D'\mu^* \\ &\equiv D'z + \Pi S'z + \Psi D'\mu^* \end{aligned} \tag{3.21}$$

where $\Pi \equiv -D'\Gamma S(S'\Gamma S)^{-1}$, which is a $(k_2 \mathrm{x} k_1)$-matrix. The $(k_2 \mathrm{x} k_2)$ matrix Ψ is defined as $\Psi \equiv (D'\Gamma D) + \Pi(S'\Gamma D)$.

For later purposes, it is useful to rewrite this equation somewhat. Recall the definition of $\widetilde{w}$ (cf. (3.16)). We will sometimes refer to $\widetilde{w}$ as "latent" portfolio shares, to indicate that they are generally not all observed. Instead w is observed. Using the fact that

$$\begin{aligned} \Psi D' - D'\Gamma &= D'\Gamma DD' - D'\Gamma S(S'\Gamma S)^{-1}S'\Gamma DD' - D'\Gamma \\ &= D'\Gamma(I_{k-1} - SS' - S(S'\Gamma S)^{-1}S'\Gamma DD' - I_{k-1}) \\ &= -D'\Gamma\left\{S(S'\Gamma S)^{-1}S'\Gamma SS' + S(S'\Gamma S)^{-1}S'\Gamma(I_{k-1} - SS')\right\} \\ &= -D'\Gamma S(S'\Gamma S)^{-1}S'\Gamma = \Pi S'\Gamma \end{aligned} \tag{3.22}$$

we can then write (3.21) as

$$\begin{aligned} D'w - D'\widetilde{w} &= D'z + \Pi S'z + \Psi D'\mu^* - D'z - D'\Gamma\mu^* \\ &= \Pi S'z + (\Psi D' - D'\Gamma)\mu^* \\ &= \Pi S'z + \Pi S'\Gamma\mu^* = \Pi S'\widetilde{w} \end{aligned} \tag{3.23}$$

So we observe that the non-zero portfolio shares are equal to their latent counterparts plus a linear combination of the latent budget shares corresponding to the zero assets. Defining $\Delta' \equiv D' + \Pi S'$, this can also be written as $D'w = \Delta'\widetilde{w}$.

Also note that the non-zero Lagrange multipliers are found as

$$\begin{aligned} S'\lambda &= S'\widehat{\mu} - S'\mu^* = -(S'\Gamma S)^{-1}\{S'z + (S'\Gamma D)D'\widehat{\mu}\} - S'\mu^* \\ &= -(S'\Gamma S)^{-1}\{S'z + S'\Gamma DD'\mu^* + S'\Gamma SS'\mu^*\} \\ &= -(S'\Gamma S)^{-1}\{S'z + S'\Gamma[DD' + SS']\mu^*\} \\ &= -(S'\Gamma S)^{-1}S'\widetilde{w} \end{aligned} \tag{3.24}$$

The econometric model of portfolio shares can now be written as follows:

$$\begin{aligned} \widetilde{w}_i &= z_i + \Gamma\mu_i^* = \overline{z}_i + \Gamma\mu_i^* + \epsilon_i \\ & \left\{ \begin{array}{c} D_i'w_i = \Delta_i'\widetilde{w}_i \\ S_i'\lambda_i = -(S_i'\Gamma S_i)^{-1}S_i'\widetilde{w}_i \end{array} \right\} \quad \textbf{iff} \quad \left\{ \begin{array}{c} \Delta_i'\widetilde{w}_i \geq 0 \quad \textbf{and} \\ (S_i'\Gamma S_i)^{-1}S_i'\widetilde{w}_i \leq 0 \end{array} \right\} \end{aligned} \tag{3.25}$$

where a subscript i has been added to index observations and $\overline{z}_i$ is the systematic part of z_i, i.e. $z_i = \overline{z}_i + \epsilon_i$. The selection matrices D_i' and S_i' vary by observation. The Kuhn-Tucker conditions guarantee that for each realization of the latent shares $\widetilde{w}_i$ there is only one unique combination of D_i' and S_i' such that the inequality conditions (3.25) are satisfied.

3.4.1 Identification

Using (3.25) we observe that the vectors z are identified up to a scaling constant from the simple probit equations explaining ownership patterns. Furthermore, we note that the elements of μ^* vary proportionately, so that *given* z we obtain $k-1$ pieces of information on Γ from the probits based on (3.25). To fully identify all parameters we need to consider the equations for the non-zero shares (3.21). The number of free elements in Π is equal to $(k_2 \text{x} k_1)$. The number of elements in Ψ is equal to $(k_2 \text{x} k_2)$, but since all elements of μ^* are proportional to each other, we can only identify k_2 elements. Thus for a given pattern of non-zero asset shares, and given z, we have $k_2 + k_2.k_1 = k_2(k_1+1) = k_2(k-k_2)$ pieces of information that can be identified from the rationed equations. To determine the total number of pieces of information on Γ that can be identified from the rationing equations, we have to account for all possible patterns of missing assets. We find that the number of restrictions imposed on Γ is equal to:

$$R(k) \equiv \sum_{k_2=1}^{k-1} \binom{k-1}{k_2} (k-k_2)k_2 \tag{3.26}$$

Since Γ is symmetric, the number of free elements in Γ is equal to $k(k-1)/2$. In addition we need $(k-1)$ scaling constants to identify z, but on the other hand the probits provide $k-1$ pieces of information on Γ, so these cancel out. In total we thus need $k(k-1)/2$ pieces of information. Table 3.8 presents the number of free elements in Γ and the number of restrictions $R(k)$ for different values of k. For $k \geq 2$, the parameters in the model are identified, at least by the simple counting rule we have applied here.

Table 3.8: *Number of assets and restrictions on* Γ

k	**Free elements of** Γ	$\mathbf{R(k)}$
2	1	1
3	3	6
4	6	24
5	10	80
6	15	240
7	21	672
8	28	1792
9	36	4608
10	45	11520

3.4.2 The Likelihood

The likelihood is based on (3.25). We consider two cases. The first case is where all asset shares are non-zero. In this case the observed shares are equal to the latent shares and the likelihood contribution is the joint density of the asset shares as implied by the first equation in (3.25). The second case is where one or more of the asset shares are zero. For observed values D_i', $D_i'w_i$, and S_i' the likelihood contribution of this observation is:

$$\begin{aligned} g(D_i'w \quad &| \quad \Delta_i'\widetilde{w}_i \geq 0,\, (S_i'\Gamma S_i)^{-1}S_i'\widetilde{w}_i \leq 0).\,\Pr(\Delta_i'\widetilde{w}_i \geq 0,\, (S_i'\Gamma S_i)^{-1}S_i'\widetilde{w}_i \leq 0) \\ &= \quad \Pr(\Delta_i'\widetilde{w}_i \geq 0,\, (S_i'\Gamma S_i)^{-1}S_i'\widetilde{w}_i \leq 0 \mid D_i'w_i).h(D_i'w_i) \\ &= \quad \Pr((S_i'\Gamma S_i)^{-1}S_i'\widetilde{w}_i \leq 0 \mid D_i'w).h(D_i'w_i) \end{aligned} \tag{3.27}$$

using the fact that $D_i'w_i = \Delta_i'\widetilde{w}_i$ and with obvious definitions for the conditional density g and the marginal density h of $D_i'w_i$. To evaluate the likelihood contribution, we need to find the marginal distribution of $D_i'w$ and the conditional distribution of $(S_i'\Gamma S_i)^{-1}S_i'\widetilde{w}_i$ given $D_i'w_i$. We assume normality of the error vector ϵ_i throughout, with $\epsilon_i \sim N(0,\Omega)$. Given this normality assumption these are straightforward exercises.

We first consider the joint distribution of $(S_i'\Gamma S_i)^{-1}S_i'\widetilde{w}_i$ and $D_i'w_i = \Delta_i'\widetilde{w}_i$. We immediately have that $(S_i'\Gamma S_i)^{-1}S_i'w_i$ and $D_i'w_i$ are jointly normal with variance-covariance matrix equal to

$$\begin{bmatrix} (S_i'\Gamma S_i)^{-1}S_i'\Omega S_i(S_i'\Gamma S_i)^{-1} & (S_i'\Gamma S_i)^{-1}S_i'\Omega\Delta_i \\ \Delta_i'\Omega S_i(S_i'\Gamma S_i)^{-1} & \Delta_i'\Omega\Delta_i \end{bmatrix} \tag{3.28}$$

The means of the marginal distributions of $(S_i'\Gamma S_i)^{-1}S_i'\widetilde{w}_i$ and $D_i'w_i$ are equal to:

$$\mathrm{E}[(S_i'\Gamma S_i)^{-1}S_i'\widetilde{w}_i] = (S_i'\Gamma S_i)^{-1}S_i'[\overline{z}_i + \Gamma\mu_i^*] \tag{3.29}$$

and

$$\mathrm{E}[D_i'w_i] = \Delta_i'[\overline{z}_i + \Gamma\mu_i^*] \tag{3.30}$$

The conditional variance-covariance matrix of $(S_i'\Gamma S_i)^{-1}S_i'w_i$ given $D_i'w_i$ is given by

$$(S_i'\Gamma S_i)^{-1}[S_i'\Omega S_i - S_i'\Omega\Delta_i(\Delta_i'\Omega\Delta_i)^{-1}\Delta_i'\Omega S_i](S_i'\Gamma S_i)^{-1} \tag{3.31}$$

and the conditional mean of $(S_i'\Gamma S_i)^{-1}S_i'w_i$ given $D_i'w_i$ is given by

$$(S_i'\Gamma S_i)^{-1}S_i'[\overline{z}_i + \Gamma\mu_i^*] + (S_i'\Gamma S_i)^{-1}S_i'\Omega\Delta_i(\Delta_i'\Omega\Delta_i)^{-1}[D_i'w_i - \Delta_i'[\overline{z}_i + \Gamma\mu_i^*]] \tag{3.32}$$

Appendix C provides the details of the likelihood for the case $k = 3$, which will be considered in our empirical work.

3.5 Results

We estimate the model for a number of different specifications of the risk aversion measure and for two definitions of wealth. The first definition of total wealth is total assets (cf. Table 3.7). The second definition is total financial assets.

3.5.1 Results for shares of gross wealth

We distinguish three asset shares: (a) a riskless asset as defined in Table 3.7; (b) a risky asset comprising growth and mutual funds, stocks, and options; (c) an "other asset" consisting of bonds, money lent out, business equity, and real estate. Despite the perhaps somewhat confusing terminology, both the "risky asset" and the "other asset" are risky. Thus the three asset shares are shares of total assets (or gross wealth, as we will sometimes call it). Although the theoretical framework presented in Section 3.3 would suggest to consider shares of net worth, rather than gross wealth, the obvious advantage of using gross wealth is that we avoid having to deal with shares in negative wealth (about 12% of the sample reports negative net worth). Table 3.9 presents estimation results for three versions of the model. The first and second version use a combination of risk attitude variables to parameterize risk aversion. For the first version, we specify risk tolerance as

$$\frac{1}{R} = \frac{1}{1 + \exp[\lambda.\mathrm{riskat1} + (1-\lambda).\mathrm{riskat3}]} \tag{3.33}$$

where the parameter λ can be estimated jointly with the other parameters in the model. For the second version, we use (3.33) but with riskat1 and riskat3 replaced by careful and precaution. In the third version the term $[\lambda.\text{riskat1}+(1-\lambda).\text{riskat2}]$ is replaced by the variable risk tolerance. The number of observations varies per version, reflecting sample selections and skipping patterns in the questionnaires, as discussed before. In all versions the estimate of γ_{12} (the off-diagonal element of Γ) had to be bounded from below to maintain positive definiteness of Γ. Somewhat arbitrarily we have restricted the quantity $\gamma_{12}/(\gamma_{11}\gamma_{22})$ to be greater than $-.99$.

We observe that γ_{11} and γ_{22} (the diagonal elements of Γ) are only jointly significantly different from zero in the first version where we use riskat1 and riskat3 as indicators of risk aversion. The version with the direct risk tolerance measure shows virtually no effect of risk tolerance on portfolio choice. The estimates of the effect of the other explanatory variables are qualitatively similar across the three versions. Income has a positive effect on the portfolio share of the risky asset and a negative effect on the portfolio share of the other asset. The effects of wealth are the opposite of those for income. Age and age squared are always jointly significant, whereas education is never significant. For the version with riskat1 and riskat3, the parameters of the estimated age functions imply that the share of the risky asset will rise monotonically with age, whereas the share of the other asset will fall after age 30. Gender does not exert a statistically significant influence on portfolio choice. The parameter λ is estimated around .5, so that both variables making up the risk tolerance variable are having an almost equal influence.

The parameters of the variance covariance matrix (ω_1, ω_2, ρ) are measured very precisely. Although one might be suspicious of the estimated standard errors, estimation of the model with simulated data (with varying sample sizes) generally produced parameter estimates that were well within two standard errors around the true parameters. Thus, it does not seem likely that the estimated standard errors are severely biased towards zero[4]

[4]Of course, this is all predicated on the assumption that the model specification is correct.

Table 3.9: *Estimation results for the full model (total assets)*

	Riskat1/3		**Careful/Prec.**		**Risk tolerance**	
Parameter/variable	**Est.**	**t-val.**	**Est.**	**t-val.**	**Est.**	**t-val.**
Risky Asset						
log-income	.132	3.53	.177	5.26	.096	1.83
gender	.036	1.43	.006	.26	.059	1.07
middle education	.049	1.57	.067	2.30	.050	1.07
higher education	.062	2.07	.077	2.63	.086	1.90
log-wealth	-.177	11.0	-.224	15.7	-.223	10.9
age	-.016	2.41	-.005	.80	-.013	1.25
age squared	.0002	3.46	.0001	1.99	.0002	2.05
constant	1.02	3.11	1.15	3.86	1.978	3.90
Other Asset						
log-income	-.177	4.64	-.214	6.94	-.153	3.33
gender	-.034	1.29	-.023	1.05	-.047	.98
middle education	-.035	1.09	-.034	1.30	.030	.76
higher education	-.058	1.83	.069	2.54	-.070	1.79
log-wealth	.324	23.4	.339	26.9	.329	18.7
age	.009	1.26	.002	.43	.016	1.74
age squared	-.0001	2.30	-.0001	1.70	-.0002	2.42
constant	1.65	5.00	-1.41	5.29	-2.13	4.87
ω_1	.246	20.7	.311	24.9	.280	16.2
ω_2	.318	28.2	.350	29.3	.302	19.4
ρ	-.859	47.4	-.912	99.5	-.904	57.3
γ_{11}	2.59	1.78	3.62	1.36	.098	.27
$\frac{\gamma_{12}}{\sqrt{\gamma_{11}\gamma_{22}}}$	-.99	-	-.99	-	-.99	-
γ_{22}	.319	1.33	.398	1.16	.007	.26
λ	.527	6.71	.607	1.84	-	-
Elements of Γ zero?	$\chi^2(2) = 42.2$		$\chi^2(2) = 2.71$		$\chi^2(2) = .07$	
Number of obs.	762		1324		516	
log-likelihood	-247.5		-574.1		-170.8	

The variables riskat1 and riskat3 are linear combinations of the underlying responses to the subjective questions listed in Section 3.2 above. In principle therefore, one can also use these responses directly in the definition of the risk tolerance measure analogous to (3.33). Table 3.10 provides the estimates of the weights of each of these variables in the risk tolerance measure (see the columns with heading "All included"). The other parameters of this version of the model have been suppressed for reasons of space. They are similar to the results reported in Table 3.9 for riskat1 and riskat3 (except for the elements of Γ; see below). The likelihood of the model with separate parameters for each of the risk attitude responses is substantially higher than in the model where these measures are combined via principal components (log-likelihood in Table 3.9 is equal to -247.5, whereas in Table 3.10 the log-likelihood is equal to -236.8). We observe from Table 3.10 that the subjective variables are dominated by "spaar2". Recall that this is the response to the question "Investing in stocks is something I don't do, since it is too risky". The fact that the word "stocks" is mentioned explicitly in this question may explain why this variable dominates all others in explaining portfolio choice. Indeed we observe that a joint test of significance of the parameters of the other risk attitude measures does not reject the null that these parameters are all zero ($\chi^2(7) = 10.57, p = .16$). If we re-estimate the model with spaar2 excluded, (see the columns with heading "Spaar2 excluded") the remaining risk attitude variables turn out to be statistically highly significant ($\chi^2(7) = 77.6, p = .000$). Since these other risk attitude variables are much less directly related to investments in stocks, it appears that they may capture genuine risk preferences and that they have a significant effect on observed portfolio choices. We also observe that the likelihood for this case is still somewhat higher than when we include riskat1 and riskat3 (i.e. the first column in Table 3.9), which include spaar2 as component.

Finally, we note that by inverting Γ we obtain an estimate of the variance covariance matrix of excess returns Σ, as perceived by households. That is, $\Sigma = \Gamma^{-1} = \begin{bmatrix} 1.62 & \\ -.563 & .198 \end{bmatrix}^{-1} = \begin{bmatrix} 30.6 & \\ .99 & 251.1 \end{bmatrix}$, where the off-diagonal element is the correlation rather than the covariance The elements of Γ are somewhat smaller than reported in Table 3.9 for the specification with riskat1 and riskat3. Due to the near-singularity of Γ, the off-diagonal elements of Σ^{-1} are very large and very sensitive to the arbitrary lower bound we imposed on the off-diagonal element of Γ. The scale of Σ is arbitrary at this point, as the scale of the risk tolerance measure (3.33) is arbitrary. To the extent that one accepts the lower bound on the off-diagonal of Γ as reasonable, one observes that the variance covariance matrix implies that the second risky asset has a higher estimate of perceived variance in returns than the first one. This is a direct consequence of the fact that the share of the risky asset is much more sensitive to the risk attitude of a respondent than the share of the other asset. For this specification, the shares of the assets do not vary significantly with age.

Table 3.10: *The estimates for the separate risk attitude variables*

	All included		Spaar2 excluded	
Variable	**Estimate**	**t-value**	**Estimate**	**t-value**
spaar1	-.079	1.26	.483	2.10
spaar2	.696	6.86		
spaar3	-.0004	.01	-.697	3.85
spaar4	.068	.93	-.052	.19
spaar5	.094	1.52	.101	.47
spaar6	.127	1.44	1.55	5.75
spaarm03	-.0004	.01	-.920	3.05
spaarm12	.04	.56	-.015	.05
spaarm13	.053	.49	.553	2.91
Tests of joint significance				
All risk att. vars.	$\chi^2(8) = 429.8$	$p = .000$		
All except spaar2	$\chi^2(7) = 10.57$	$p = .16$	$\chi^2(7) = 77.6$	$p = .000$
log-likelihood	-236.8		-249.1	

3.5.2 Results for shares of gross financial wealth

The shares in financial wealth are defined as follows: (a) the non-risky asset defined in Table 3.7; (b) a risky asset comprising growth and mutual funds, stocks, and options; (c) an "other asset" consisting of bonds and money lent out. Tables 3.11 and 3.12 present results analogous to Tables 3.9 and 3.10, but now for shares of financial assets. In contrast to the case of shares in total assets, the elements of Γ need not be restricted to guarantee positive definiteness. The estimates of Γ are jointly significant for both the version with riskat1 and riskat3 and the version with careful and precaution, but not for the version with the direct risk tolerance measure. In the latter case we moreover had to restrict the off-diagonal element of Γ to avoid indefiniteness. The pattern of the signs of the estimated parameters is almost identical in Tables 3.9 and 3.11. Hence our discussion of Table 3.9 carries over to Table 3.11. The estimates of Γ cannot be compared directly across the first two specifications in Table 3.3, as the scales of the risk attitude measures differ. The joint test of significance of the elements of Γ yields smaller p-values for the second specification than for the first one, but the number of observations is also considerably larger in the second specification.

Regarding Table 3.12, the variable spaar2 once again dominates, but now even in the version with spaar2 included the other risk attitude variables remain significant. In the version with spaar2 excluded that is even more the case. The estimates of Γ and Σ are now $\Sigma = \Gamma^{-1} = \begin{bmatrix} 1.26 & \\ -.419 & .298 \end{bmatrix}^{-1} = \begin{bmatrix} 1.48 & \\ .682 & 6.27 \end{bmatrix}$ Once again, the estimated perceived variance in returns of the second risky asset is larger than the first one. The numbers in Σ are much more reasonable than for total assets due to the fact that the matrix Γ is much better conditioned.

Table 3.11: *Estimation results for the full model (financial assets)*

	Riskat1/3		**Careful/Prec.**		**Risk tolerance**	
Parameter/variable	**Est.**	**t-val.**	**Est.**	**t-val.**	**Est.**	**t-val.**
Risky Asset						
log-income	.189	1.90	.267	2.06	-.021	.08
gender	.030	.43	-.018	.19	-.051	.18
middle education	.046	.54	.035	.30	.113	.44
higher education	.085	1.02	.048	.41	.190	.80
log-wealth	-.030	.56	-.333	5.93	-.451	4.27
age	-.018	.98	-.023	.94	-.011	.22
age squared	.0002	1.36	.0003	1.19	.0001	.25
constant	-1.11	1.12	3.06	2.41	6.97	2.50
Other Asset						
log-income	-.201	2.28	-.266	2.71	-.090	.45
gender	-.003	.04	.002	.03	.016	.07
middle education	-.025	.33	.047	.52	-.074	.39
higher education	-.090	1.19	-.006	.06	-.138	.78
log-wealth	.255	8.85	.421	10.9	.496	6.27
age	.007	.42	.012	.67	.010	.26
age squared	-.0001	.59	-.0002	.87	-.0001	.21
constant	-1.47	1.90	-3.24	3.55	-5.76	2.80
ω_1	.553	9.95	.934	11.9	1.09	6.84
ω_2	.566	14.5	.860	15.2	.974	7.85
ρ	-.771	11.1	-.955	107.9	-.970	100.3
γ_{11}	.933	6.46	23.8	2.85	1.30	.58
$\frac{\gamma_{12}}{\sqrt{\gamma_{11}\gamma_{22}}}$	-0.125	.36	-.916	3.77	-.99	-
γ_{22}	.011	.21	6.86	3.06	.437	.59
λ	.536	7.92	.380	1.81		
Elements of Γ zero?	$\chi^2(3) = 91.43$		$\chi^2(3) = 180.8$		$\chi^2(3) = .36$	
Number of obs.	755		1310		512	
log-likelihood	-629.4		-1071.2		-403.0	

Table 3.12: *The estimates for the separate risk attitude variables (financial assets)*

	All included		Spaar2 excluded	
Variable	**Estimate**	**t-value**	**Estimate**	**t-value**
spaar1	-.077	1.21	.681	2.24
spaar2	.668	6.43		
spaar3	.038	.77	-.445	1.80
spaar4	.077	1.09	-.263	.83
spaar5	.103	1.69	-.012	.05
spaar6	.180	1.98	1.76	7.06
spaarm03	-.067	.79	-1.29	3.92
spaarm12	.055	.67	-.134	.40
spaarm13	.022	.20	.701	3.22
Tests of joint significance				
All risk att. vars.	$\chi^2(8) = 416.2$	$p = .000$		
All except spaar2	$\chi^2(7) = 21.5$	$p = .003$	$\chi^2(7) = 73.3$	$p = .000$
log-likelihood	-621.5		-629.22	

3.6 Concluding remarks

We have explored the explanatory power of a number of different subjective measures of risk aversion for the explanation of portfolio choice. The variable risk tolerance, which has the firmest grounding in economic theory, appears to have very little explanatory power. There are a few different possible explanations for this. First of all, the question is quite complicated and many respondents may have a hard time understanding the exact meaning of the question. Secondly, the question conditions on a respondent's current situation. So for instance a risk tolerant individual with a risky portfolio may be induced to choose a safe income stream, since she is already exposed to considerable risk. Conversely, a risk averse individual with a very safe portfolio can afford to choose a riskier income path. In both cases the observed relationship between the measured risk tolerance and portfolio choice is attenuated.

The variables riskat1 and riskat3 extracted from a factor analysis of ad hoc measures appear to be doing considerably better in terms of explanatory power, both for total assets and for financial assets. Yet, closer analysis reveals that most of the explanatory power of these variables comes from one question, which asks directly for the subjective evaluation of the riskiness of investing in stocks. Omitting this variable shows that both in a model with all assets and in a model with just financial assets the ad hoc measures still retain a highly significant influence on portfolio allocation. Interestingly, in the model for financial assets the measures careful and precaution also contribute significantly to the explanation of portfolio shares. This reinforces the notion that intuitive ad hoc measures may be more powerful in explaining portfolio choice than theory based, but complicated, risk tolerance measures.

Thus, the chapter provides evidence that individually measured risk preference variables help explain portfolio allocation in line with economic theory. Perhaps surprising to economists, simple intuitive measures of risk preferences appear to be more powerful predictors of portfolio allocation than more sophisticated measures with a firmer basis in economic theory. Yet, for empirical analysis this may be good news. The ad hoc questions are much easier to ask and demand considerably less imagination of respondents, which may be exactly why the simple measures work better.

The modelling of incomplete portfolios by explicit use of Kuhn-Tucker conditions is fairly straightforward and estimation of the resulting model yields well determined estimates of a number of key parameters. So far we have restricted ourselves to just three broad group of assets. The set-up can be easily generalized to more than three assets, although the computational cost will undoubtedly increase.

Chapter 4

The Personal Discount Rate: Evidence From Swiss Pension Funds

4.1 Introduction

The personal discount rate is one of the key elements of intertemporal decision making.[1] Nonetheless, as Frederick, Loewenstein and O'Donoghue (2001) have recently shown, the numerous empirical attempts to measure discount rates over the past three decades have failed to identify any robust estimates across studies. Most of these studies, however, rely on experiments with a potentially limited generalizability to real world choices.

A particularly compelling field study in terms of magnitudes of stakes and the credibility of pay–outs has recently been presented by Warner and Pleeter (2001). As part of a US military down–sizing program volunteers were given the choice between an annuity over a number of years (related to previous years in service) and a one–time lump–sum payment, both depending on the leaver's previous salary and years of service. A large majority of the volunteers chose the lump–sum although the implicit discount rate — the rate at which the present value of the annuity and the lump–sum were equal — amounted to 17% (in nominal terms). The authors then estimate the underlying discount rates and find values of 0–30. It is important to point out, however, that all these volunteers were at a specific stage of their life–cycle and faced constraints that are presumably different from constraints people face at other ages. Most importantly, borrowing constraints and downpayment requirements for mortgages may have influenced the choice much more than the discount factor.

We use a sample of individuals facing a similar choice between a lump sum payment and an annuity upon retirement in Swiss pension funds to provide some additional evidence.[2] We show that in a setting with even larger stakes (5 to 10 times the amount the military personnel faces), many more people (in fact a large majority) indeed choose the annuity option. Apparently, many of the constraints individuals face at age 30 are gone or have changed at age 65.

Our chapter has two goals: The first is to explain why a decision between a lump–sum and an annuity may be influenced by constraints that vary over the life–cycle. This may lead to differences in the measured discount rates over the life–cycle even if the underlying discount rate were constant. The second goal is to provide some additional evidence to the findings of Warner & Pleeter from an equally reliable sample that is not plagued

[1] See, for example, Caroll & Samwick (1997) and Gourinchas & Parker (2001).

[2] Occupational pension schemes, constituting the second pillar of Swiss old age insurance, are privately managed (usually by the firm), but are mandatory for all workers earning a yearly income of more than 22'000 Sfr ($\approx$ 14'000 US$) and are, therefore, heavily regulated. The vast majority of Swiss workers is covered by such a scheme.

by selection bias and offers an even more impressive real choice in terms of magnitude between the two options.

Unlike many other contributions in the area, we do not primarily focus on potential departures from the assumption of a single underlying discount rate or other choice anomalies, but like to point out that different estimates may be inherently related to an agent's position in the life–cycle.

In the following Section 4.2 we provide some theoretical reasons why measurements of personal discount rates may suffer from an age–dependent bias even if the underlying discount rate was constant during the entire life. Section 4.3 discusses important aspects of a choice between an annuity and lump sum capital at retirement, and Section 4.4 presents the corresponding empirical evidence. Section 4.5 concludes the chapter.

4.2 Why measurements of personal discount rate may be age–dependent

Over the life–cycle a typical agents faces different constraints that may bias her choice between an annuity and a lump–sum even if the agent was indifferent between the two in the absence of the constraints. To illustrate the different factors we compare the typical Warner & Pleeter individual with a person at retirement as in our sample.

4.2.1 Borrowing constraints, flexibility and (ir)reversibility of choice

As a large literature has shown[3], borrowing constraints are likely to bind at an early stage of an agent's professional career, while they are very unlikely to be important around the retirement age. A lump–sum at young ages may, therefore, ease the borrowing constraint a bit, and allow, for example, the downpayment for a house. In this case, the agents is willing to give up some of the direct payoff of the annuity in favor of relaxing the borrowing constraint.

Closely related to borrowing constraints and similar capital market imperfections is the potential (ir)reversibility of choice: *Ceteris paribus*, rational agents should choose the more flexible option. In Warner & Pleeter's case this is most probably the capital option,

[3] Caroll & Samwick (1997), Samwick (1998) and Gourinchas & Parker (2001) stress the importance of borrowing constraints for life-cycle decision making.

which can be easily translated into a stream of regular payments over a certain period. Note also that once the agent has chosen the annuity, the cost he has to incur to get a lump sum back is high due to the high interest rate on (unbacked) small loans. This trade–off in favor of a lump–sum is far less apparent at age 65. Although it is still relatively cheap to transform the lump–sum into a stream of payments for a limited time, it is a lot more difficult to get the original annuity option back as the private annuity market is plagued by adverse selection effects. Transforming an annuity back into a lump–sum is easier if the loan can be backed up by assets (such as housing) which is far more likely at age 65 than at age 30. The elderly will, therefore, be more likely to choose the annuity than the young even if the underlying discount rate was the same. This will lead to an upward bias of estimated discount rates at younger ages.

4.2.2 Magnitude effects

A large body of literature (Ainslie and Varda Haendel, 1983; Thaler, 1981; Loewenstein, 1987 among others) points out that small outcomes are discounted at a higher rate than large ones.[4] Although primarily viewed as a choice anomaly, some aspects of this "magnitude effect" may be explained by the impact of neglected constraints or neglected aspects in a person's utility function.

Let us first consider the case of an individual with a low level of accumulated capital. An annuity, even small, may be detrimental to the eligibility for income support programs for a young agent. The same is true for retirees who, under certain circumstances, can apply for additional support. In most programs, wealth is only taken into account if it exceeds a certain threshold level while regular non–labor income counts from the first dollar. It is thus optimal to choose the lump–sum option for low levels of capital.

Other than on magnitude effects, an agent's choice between an annuity and a lump sum payment may depend on the following factors:

1. differential mortality: accumulated capital is a good indicator of a person's lifetime income and social status.[5] The probability of choosing the lump sum is decreasing

[4]Shane, Loewenstein and O'Donoghue (2001) report that "... In Thaler's (1981) study, for example, respondents were, on average, indifferent between \$15 immediately and \$60 in a year, \$250 immediately and \$350 in a year, and \$3000 immediately and \$4000 in a year, implying discount rates of 139%, 34% and 29% respectively." (p.19). In other words, for small stakes agents generally prefer an early payment to a deferred one even in the choice implies a high discount rate. In our case, the lump sum option offers such an early payment.

[5]In Switzerland, a person belongs to one pension fund only by law.

in capital. This effect is stronger for low levels of capital.

2. consumption and bequest motives: the higher the annuity, the lower the marginal utility of consumption at the given level. People might prefer to hold their pension wealth in the form of capital to be able to bequeath it to their children (at least partially).[6]

3. preferential tax treatment: In Switzerland, there is clearly a tax advantage to withdraw the accumulated pension wealth in the form of a lump sum. This effect is much stronger for high and very high levels of capital.

4. investment opportunities (and skills): It is much easier to find good investment plans for larger levels of capital. Depending on the financial health of the pension fund, private investment might be more profitable, provided the capital is high enough.

To summarize, magnitude effects and differential mortality should lead to a decreasing probability of choosing the lump sum for low and moderate levels of pension wealth, whereas the latter three factors enlisted above should lead to an increase in the likelihood of choosing the lump sum at relatively high levels of capital. Taken together, these two effects should lead to a U–shaped relationship between the probability of choosing the lump sum option and the total stock of capital at retirement. As Warner & Pleeter investigated choices over relatively small sums, it is thus not surprising that they find higher implicit discount rates.

4.2.3 Insurance aspects

An annuity at age 30 obviously provides little insurance against various contingencies especially if it is relatively small. Not so the lump sum: The dismissed agents are probably job–less and will need a fall back amount of money for the first few months. Not finding a job during the relatively long period of the annuity, on the other hand, is a low probability event. This is even more true if agents are unable to borrow. As Deaton (1991) shows, the presence of liquidity constraints reinforces the precautionary motive for saving, even if people are impatient. In such a framework, assets are not desired for their own sake, but to buffer fluctuations in income. When income is low, the agent dissaves, as even the

[6] Of course agents can save for a bequest independently from the accumulated capital at retirement, but there is the risk to die prematurely and thus leave a small amount of money. The lump sum payment guarantees a certain level of bequest.

last unit of cash in hand is worth more now than it is expected to be tomorrow; when income is high, the so-called "saving-for-a-rainy-day" will take place. It is then clear that a lump sum payment would ease the borrowing constraints much more than an annuity.

In a pension setting the insurance against longevity is the more urgent concern. Here a lump sum provides far less insurance than the annuity. A consequence of the insurance against longevity is that we should observe different (unadjusted) discount rates due to differential mortality according to gender, marital status and wealth/income.

Insurance aspects should thus bias the estimates of discount rates upwards for young agents and downwards for retired people.

4.2.4 Other factors

Whether the annuity is indexed to inflation is another important determinant of the choice between the two options. In case it is not indexed as in the military downsizing program, not only will the true discount rate be lower than the measured unadjusted one, but uncertainty about the future path of inflation will make the certain capital option more attractive.

An individual may choose the capital option if he thinks he can obtain a better return than the one offered from the annuity scheme. Investment opportunities will most likely depend on the total amount to be invested, but also on investment abilities. The higher average capital stock at retirement may facilitate alternative investments especially if investment abilities are correlated with wealth.

4.3 The choice between annuity and lump sum capital at retirement

The cut–off rate is the discount rate that equalizes the present value of the capital and the annuity option. As it makes the agent indifferent between the lump sum and the annuity option, the cut-off rate provides a first estimate of how people choose. We first present a general derivation of cut–off rates as a function of gender, marital status, and age difference between the spouses. Then we briefly explain how cut–off rates were computed in the data. We use differential mortality across gender and marital status, but unfortunately not across income groups due to the non–availability of corresponding data.

4.3.1 Computing cut–off rates

Let us introduce the following notation: M is the main claimant,i.e., the person who has accumulated the claim to the pension system, and S is his/her spouse. The pensioner's spouse S is d years older than the main claimant. M retires at age J with an accumulated capital stock of K.[7] Upon retirement, the accumulated capital is either withdrawn as a lump sum or translated into a life–long annuity using the age–dependent conversion factor γ, defined as

$$\gamma = \frac{B}{K} \tag{4.1}$$

where B denotes yearly benefits[8].

In case M dies and is survived by his/her spouse S, the latter gets a survivor benefit, which is a certain fraction λ of the main benefit B. For single, divorced or widowed agents, the analysis is similar, though much simpler, as joint survival probabilities do not have to be taken into account.

In virtually all Swiss pension funds, pensions are indexed to the consumer price index, so they stay (at least) constant in real terms. Often they even grow in real terms. Let us assume for the moment, that pensioners expect their real pension to grow at a real rate g.

When computing the cut–off discount rate we have to know the conditional probability of survival to age j for both spouses. Survival probabilities are allowed to depend on marital status, and the joint probability of survival is a function of the age difference d between the spouses. The discount rate is denoted ρ. The present value of all future benefits from retirement age on can be written as

$$\text{PV} = \frac{1}{\Psi_J^M} \sum_{t=J}^{\infty} \left(\frac{1+g}{1+\rho}\right)^{t-J} B \times \begin{cases} & (\Pr[M \text{ alive},\ S \text{ alive}] \\ + & (\Pr[M \text{ alive},\ S \text{ dead}] \\ + & (\Pr[M \text{ dead},\ S \text{ alive}] \times \lambda \end{cases} \tag{4.2}$$

Combining (4.2) with (4.1), we can implicitly compute the cut–off discount rate ρ^* that makes agents indifferent between a lump sum capital payment and a life–long annuity in present value terms as follows:

$$\frac{1}{\gamma_J} = \frac{1}{\Psi_J^M} \sum_{t=J}^{\infty} \left(\frac{1+g}{1+\rho^*}\right)^{t-J} B \times \begin{cases} & (\Pr[M \text{ alive},\ S \text{ alive}] \\ + & (\Pr[M \text{ alive},\ S \text{ dead}] \\ + & (\Pr[M \text{ dead},\ S \text{ alive}] \times \lambda \end{cases} \tag{4.3}$$

[7] In a defined benefit system, this is the implicitly defined capital stock that corresponds to the annuity. Note that many funds allow a partial withdrawal of capital even in a defined benefit system.

[8] Age and the conversion factors display a positive pairwise correlation coefficient, equal to .5976.

Note that this expression is similar to the one used in Warner & Pleeter, but is adjusted for (joint) survival and differential mortality by marital status. From equation (4.3) we can infer that the cut–off rate ρ^* is:

- a decreasing function of the age difference d between the spouses, where d can be negative or positive. If d was positive, the probability that (s)he will survive the main claimant will be low and the expected length of joint survival short.[9] The cut–off rate will therefore be relatively low and more likely to be below the agent's discount rate, making the lump–sum option more attractive.

- an increasing function of the conversion factor γ (or, in other words, the generosity of the pension system).[10] An increase in the conversion factor leads to a decrease in the left-hand side of the equation. In order to let the equation still hold, the right-hand side must decrease as well, and that would imply, *ceteris paribus*, that the cut-off rate must increase.

- an increasing function of survival probabilities, which in turn are functions of gender, marital status, and socioeconomic variables (differential mortality).

- an increasing function of the expected annuity growth rate.

The lower the cut–off rate, the more likely the agent chooses the capital option as his/her personal discount rate exceeds the cut–off rate. Figure 4.1 depicts cut–off rates by marital status, gender, and age at retirement (only for men) as a function of the age difference between the spouses.[11] The annuity is obviously worth relatively more the younger the spouse. This effect is much stronger for men than for women, as the probability of the latter being survived by her husband is relatively small due to a higher expected lifetime for women. Interestingly, the theoretical cut–off rates for married men (retiring at age 62) and married women with an average age difference of three years (as in reality) is almost equal.

[9] Married individuals have a lower mortality rate than single or widowed ones.

[10] The higher the conversion factor, the higher the value of the annuity compared to the accumulated pension wealth. A plan with a high conversion rate for a given retirement age thus offers a better deal, but this does not affect the capital.

[11] For this figure we use the most recent Swiss mortality rates differentiated by gender x marital status.

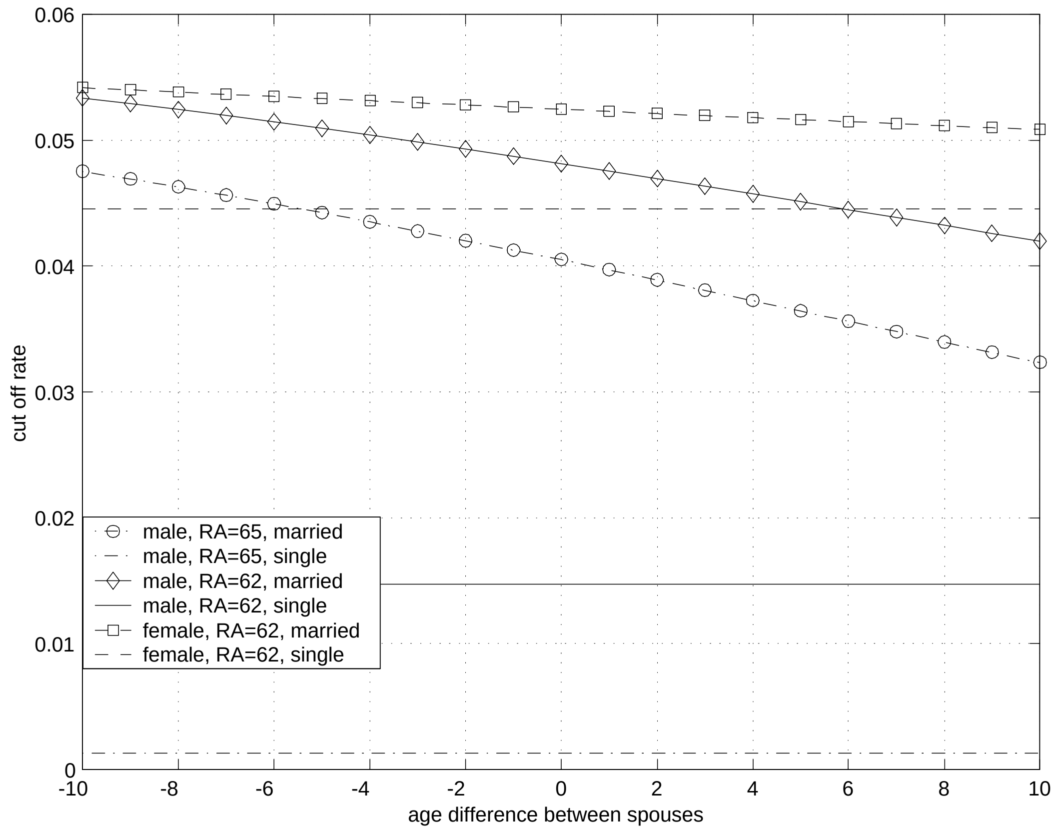

Figure 4.1: *Cut–off rates between lump sum and annuity depending on gender, marital status (no symbol = single), retirement age (RA, only for men), and age difference between spouses (negative numbers mean than that spouse is younger). For men, cut–off rates are depicted for the legal retirement age 65 and for retirement at age 62, at which most companies offer the full retirement benefits. Parameters for figures:* $g = 0$, $\lambda = 0.6$, $\gamma = 0.072$, *equal tax treatment.*

4.3.2 Computing cut–off rates in the data

From the data, we know age at retirement, marital status[12], the rate of growth of the annuity g (usually 0), and the conversion factor γ, but not the age difference between the spouses. In computing the individual cut–off rates ρ^*, we, therefore, use the average observed age difference in Switzerland, which is approximately three years.

Note that the presence of children in education (only observed with male pensioners) is a signal for a much younger wife. Children should make annuity the preferred option, not only because they are entitled to additional benefits, but also because the survivor benefit is worth a lot more for these couples on average.

4.3.3 Empirical predictions

Combining the information gathered in the previous sections, we should observe the choice between the two options to depend on:

1. *The gender* should only matter for single agents, as the present value of future benefits is very similar for married men, married women, and even single women. Single men, on the other hand, should be more likely to choose the capital option relative to women and married men.

2. *Young children* usually trigger a sizeable additional benefit, which makes the annuity option more attractive. This effect is reinforced by the fact that the presence of minor children usually means a much younger wife.

3. *The size of the capital stock at retirement* captures both individual characteristics (in particular differential mortality) as well as general differences in investment opportunities and insurance aspects. Following the arguments in Section 4.2, we expect a U–shaped dependence of the probability of choosing the capital option as a function of total capital at retirement.

4. *The generosity of the pension system,* measured by the conversion factor γ. The higher γ the higher the present value of the annuity compared to the capital option.

5. *The age at retirement* should not influence the choice to a large extent as it should be captured by a lower conversion factor.

[12] With the exception of one company, where we assume that all agents are married as the majority of individuals at the age of retirement.

The tax treatment for the two options is very similar: In most cantons (the Swiss states), a lump sum capital payment is converted into an annuity stream, using the conversion factor provided by the pension fund (equation (4.1)). The marginal tax rate computed from the corresponding annuity stream is then applied to the entire capital stock in case of a lump sum payment. If at all, the tax structure slightly favors the capital option as additional income from other sources, which increases the effective marginal tax rate under the annuity option, is not taken into account for the lump sum capital option. For married women at retirement, moreover, the tax treatment of the capital option is much more attractive as an annuity is taxed at the marginal tax rate the married couple faces.

4.4 Empirical Evidence

4.4.1 The dataset

In the empirical analysis we use data collected at the individual level from 9 Swiss companies, both public and private, active in several industrial branches. They are SSB (railways), Thurgauer (civil servants), SIG (several industry firms), Kambly (food), Alusuisse (metal industry), Unilever (chemical industry), PK-Manor (clothing), NCR (computers) and ABB (industry).

The dataset consists of 1449 observations.[13] Each company provides data about individuals after retirement or workers who have already chosen the option of the annuity or lump-sum capital. We are given information about date of birth, marital status, number of children under 18/25[14], date of retirement, legal retirement age, yearly pension and yearly additional pension for children, total capital at retirement, lump-sum capital paid out, conversion factor[15] (γ).

Most of the variables are self-explanatory. Gender takes the form of a dummy, whose value is 0 for females and 1 for males. Males and females represent 73 and 27 percent of the sample, respectively. Similarly, marital status is a categorical variable, whose value is

[13] The cleaning and editing of the data has been a considerable task. Firstly, the data format provided varied widely across companies. Secondly, much of the relevant information for the project had to be imputed from other sources (reglementation) or from a combination of available data. In many cases the information could only be gathered from a personal interview with the respondible pension fund manager.

[14] Children under age 18 are always eligible for additional benefits. For those over 18, but under 25, a pension is available for disabled children and those still in school.

[15] In Switzerland the conversion factor is usually 60%.

1 for singles, 2 for married, 3 for separated, 4 for widowed and 5 for divorced. The great majority is represented by married individuals (79%), followed by divorced (8%), singles (7%), widowed (5%) and separated (1%). The sample consists of individuals whose ages range from 54 to 70 years, whereas their age at retirement ranges from 52 to 66. Figure 4.2 depicts the distribution of the age at retirement for men and women.

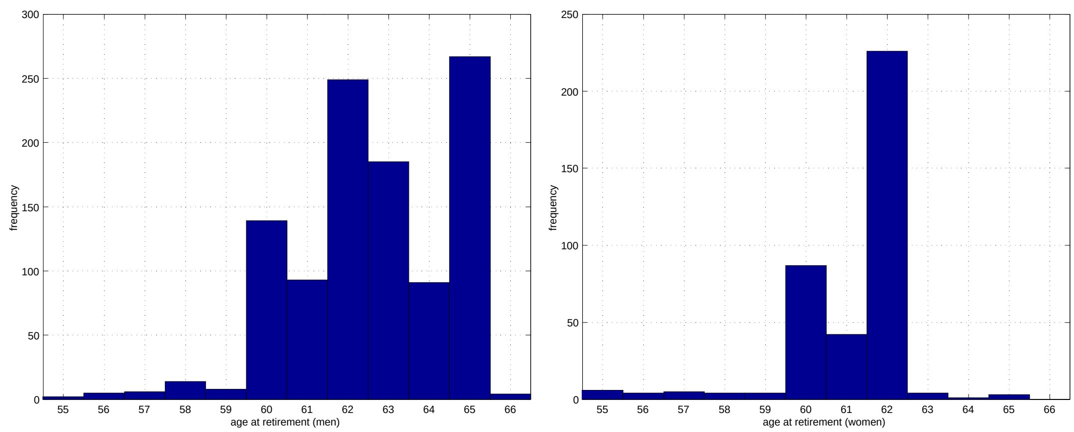

Figure 4.2: *Distributions of age at retirement for men (left-hand side) and for women (right-hand side)*

The distribution of age at retirement has a triple–peak profile for men and a double–peak profile for women, at ages 60 and 62, and 65 (for men only). This is a result of the fact that the latter is the current legal age of retirement for men, while 62 is the legal age of retirement for women, but also the age at which many pension funds offer full benefits even for men. We notice however another important peak at age 60. This is often the lowest age for which early retirement packages are offered at relatively good conditions.

The capital stock upon retirement (or the annuitized rent) is a sufficient statistics for the income during lifetime, so that all the information before retirement is redundant. The conversion factor (γ) is the factor at which is capital is translated into an annuity. The cut-off discount rate (ρ^*) is the rate that should make the agent indifferent between the lump sum and the annuity option if equation (4.3) would hold for each observation. The variable "margin" is 1 for individuals who choose a combination between an annuity and a lump sum payment which is *not* the standard option offered by the respective pension fund.[16] On the basis of this piece of information we can infer what individuals actually

[16]For these individuals, the present value of their annuity stream should exactly be equal to total

choose among a full annuity, a partial or a full lump-sum payment. We then build the variable "choice" in the form of a categorical variable, whose value is 0 for full annuity, 1 for partial lump sum and 2 for full lump sum.

Only some variables are available for the complete sample, namely age at retirement, gender, total capital accumulated at retirement, fraction of total capital paid out as a lump sum, conversion factor, margin and choice. As for the other variables, the number of observations is somewhat smaller. Table 4.1 provides summary statistics for some of the variables we use for empirical analysis.

4.4.2 Individual preferences over options

As mentioned above, individuals in the sample can choose among three different options: a full annuity, a partial or a full lump sum payment. Table 4.2 reports a number of relative frequencies of the choice variable by several demographic and socio-economic characteristics and p-values referring to χ^2-tests of the null that the distribution of preference over the three possible options is the same across different values of a characteristic. We observe that along all characteristics the annuity is by far the most preferred option. This reflects preferences over the whole sample, where more than 60 percent of observations choose the annuity. Females choose the (full) lump sum payment more than males (31.87 percent versus 19.85 percent); the annuity payment is the most preferred option among single individuals (74.67 percent) and marital status does not seem to have a significative impact on the choice. These findings are not consistent with the predictions of the theoretical model described in Section 4.3. Interestingly, differences in preferences are strongly significant along the "company" dimension, suggesting a relevant role of company fixed effects in the personal choice.

We then explore preferences by company more deeply. Seven out of nine companies provide an annuity as standard option, and allow for a partial or full lump sum payment as an alternative. The remaining two companies provide a partial lump sum payment (usually a multiple of the last working year's salary) as the standard option. Table 4.3 shows that overall the standard option is preferred by more than 2/3 of the sample. For six companies this percentage is even bigger, reaching a maximum of 97.8%; for two companies (SIG and ABB) preferences over options are basically evenly distributed, with a slight predominance of the standard one; in only one case (Kambly) the alternative

capital at retirement. The corresponding cut–off rates therefore provide a first estimate of the prevailing discount rate (mean cut–off rate for these agents is 4.00%).

Table 4.1: *Summary statistics for some relevant variables*

Variable	**Mean**	**Std.**	**Min**	**Max**	**# obs.**
Age	63.32	2.35	54	72	1211
Age at retirement	62.27	1.93	52.17	66	1449
Marital status:					1123
single (men: 4.6%, women: 12.6%)	6.7%				75
married (men: 81.4%, women: 73.1%)	79.2%				889
divorced	8.5%				95
widowed	4.8%				54
separated	0.9%				10
Gender (1 = male)	.734	.442	0	1	1449
Children ($\leq$ 18/25 y.)	.043	.268	0	3	1032
Yearly pension (incl. child benefits)	22033	19620	0	191925	1449
Total capital at retirement **	401250	283706	1560	3325360	1449
Lump-sum capital paid out	78171	159889	0	1089898	1449
Fraction of total cap. paid out	.242	.385	0	1	1449
Conversion factor (gamma)	.0682	.0039	.0510	.077	1449
Cut-off discount rate	.0391	.010	-.0072	.0533	1449
Non–standard option (= 1)	.3168	.4654	0	1	1449
Margin	.1338	.3406	0	1	1449
Choice	.595	.838	0	2	1449

*(** average capital: married men = 501'315; single men = 392'423; married women = 96'808; single women = 289'720)*

Table 4.2: *Individual preferences over options by gender, marital status and company (percentages)*

Characteristic	Annuity	Partial lump-sum	Full lump-sum	Total n. obs.
Female	60.36	7.77	31.87	386
Male	64.72	15.43	19.85	1063
p-value	.001			
Single	74.67	6.67	18.67	75
Married	65.06	12.13	22.82	890
Sep. and div.	62.86	14.29	22.86	105
Widowed	68.52	7.41	24.07	54
p-value	.56			
PK-Manor	69.64	13.09	17.27	359
SBB	97.84	1.62	0.54	185
Thurgauer	-	12.82	87.18	39
SIG	56.31	19.08	24.62	325
Kambly	33.96	-	66.04	53
Alusuisse	90	10	-	70
Unilever	9.30	-	90.70	43
NCR	93.33	6.67	-	15
ABB	57.78	19.17	23.06	360
p-value	.000			
Total sample	63.56	13.39	23.05	1449

option overcomes the standard one. These figures suggest that there may be a sort of "acquiescence bias" driving people's choices[17].

Table 4.3: *Distribution of preferences over options by company (percentages)*

Company	Standard Option	Alternative Option
PK-Manor	69.6 (annuity)	30.3
SBB	97.8 (annuity)	2.2
Thurgauer	87.2 (partial l.s.)	12.8
SIG	56.3 (annuity)	43.7
Kambly	34.0 (annuity)	66.1
Alusuisse	90.0 (annuity)	10.1
Unilever	90.7 (partial l.s.)	9.3
NCR	93.3 (annuity)	6.7
ABB	57.8 (annuity)	42.2
Total	68.3	31.7

4.4.3 Empirical results

Lump-sum payments

We start reporting (Table 4.4) some summary statistics of the cut-off discount rate for each of the choices actually made by the individuals in the sample. Mean values (but also maximum and minimum values) are virtually the same across choices, suggesting a poor explanatory power of the cut-off discount rate. Moreover, they go in the wrong direction, as people choosing the annuity should display a higher value for the mean cut-off discount rate and, similarly, a lower cut-off discount rate should correspond to the choice of a (full) lump sum payment.

The determinants of choosing a (partial) lump sum payment are analyzed for two base specifications. Company fixed effects are included to account for differences in the characteristics of the pension scheme (regressions II and IV). Ordered probit estimates are reported in Table 4.5

[17] The expression "acquiescence bias" (Hurd, 1999) or "status-quo bias" or "friendliness effect" refers to a systematic bias caused by some respondents tending to agree with whatever is presented to them.

Table 4.4: *Summary statistics for cut-off discount rates*

Choice of individuals	Mean	Max	Min	N.Obs.
Annuity	.038	.053	-.007	921
Partial lump sum	.040	.053	-.005	268
Full lump sum	.041	.053	-.004	260

In regression I we run a simple ordered probit with the choice made by individuals as dependent variable and control for basic background individual characteristics such as gender, having children less than 18 or 25 years old, age at retirement and stock of capital accumulated at retirement[18]. We find that age at retirement is positively, though not significantly, related to the preference for a lump–sum payment: the higher the age at retirement the higher the probability of choosing a lump sum payment. Contrary to our model's predictions, males are more likely to choose a (partial) lump sum payment.

As expected (see Section 4.3), the stock of capital accumulated at retirement plays an important role. In the regression we use the variable in logs and we add a quadratic term in order to capture a potential non–monotonic relation. The capital function corresponding to regression I is depicted in Figure 4.3. We can see that the amount of total capital at retirement is negatively related with the probability of choosing a lump sum payment until the value of 291,000 Swiss Francs (around 184,000 USD); after that value the relation becomes positive. These findings are robust to the addition of company fixed effects (regression II)[19].

Next we include (regression III) two extra variables, namely the cut-off discount rate

[18] In a previous version we also included marital status, but in doing so one company (SIG) dropped because that piece of information was missing. After observing the complete irrelevance of marital status in explaining the choice between an annuity and a lump sum payment, we then decided to excluded this variable: as a consequence we gained 325 observations.

[19] The only difference is that for the specification with company fixed effects the age at retirement becomes significant.

Table 4.5: *Determinants of choosing a lump-sum payment (ordered probit estimates)*

Regression	I		II		III		IV	
	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t
Expl. variables	(Std)		(Std)		(Std)		(Std)	
Gender (male=1)	.227	2.02	.266	2.08	.263	2.30	.292	2.25
	.113		.128		.114		.130	
Total capital (log)	-2.96	5.49	-3.87	6.56	-3.00	5.56	-3.67	6.27
	.539		.589		.540		.586	
Total capital^2 (log)	.114	5.02	.150	6.00	.115	5.08	.141	5.68
	.022		.024		.023		.025	
Age at retirement	.007	.40	-.045	2.03	-.067	2.43	.084	2.13
	.018		.022		.028		.039	
Cut-off discount rate					10.54	2.87	5.19	1.23
					3.67		4.22	
Conversion factor (γ)					45.56	3.36	-96.17	4.00
					13.57		24.07	
Number of observations	1449		1449		1449		1449	
Pseudo R^2	.034		.200		.044		.200	
Company fixed effects	NO		YES		NO		YES	
Log-Likelihood	-1253.7		-1038.1		-1239.7		-1029.8	

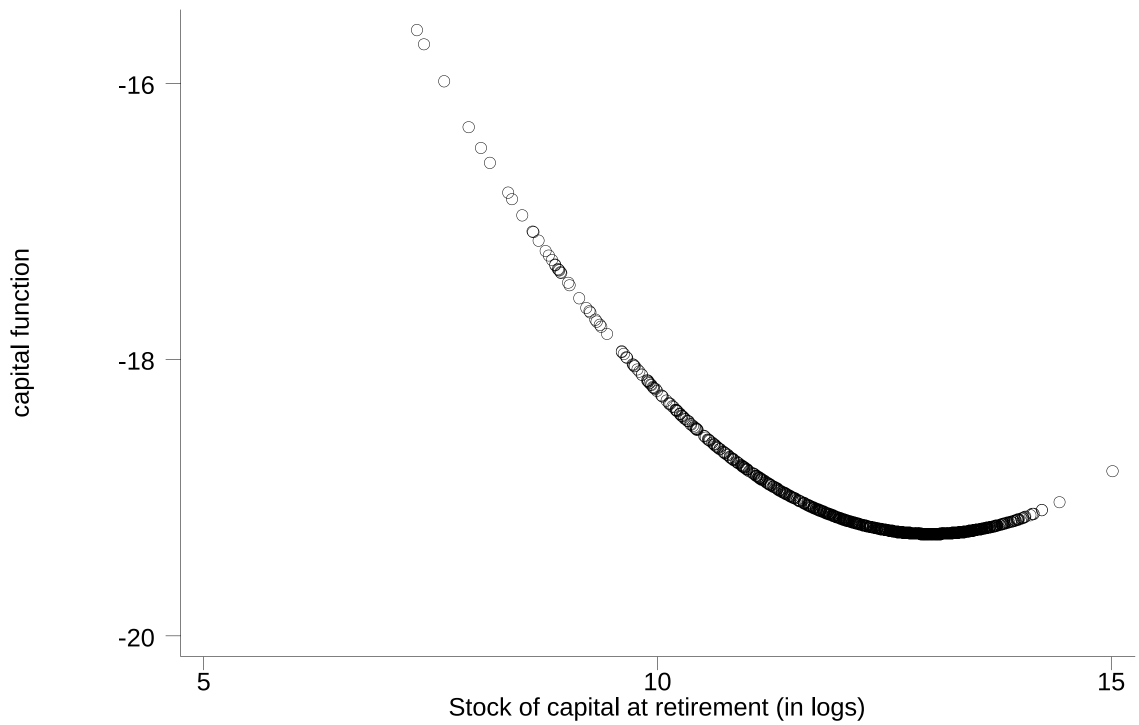

Figure 4.3: Capital function

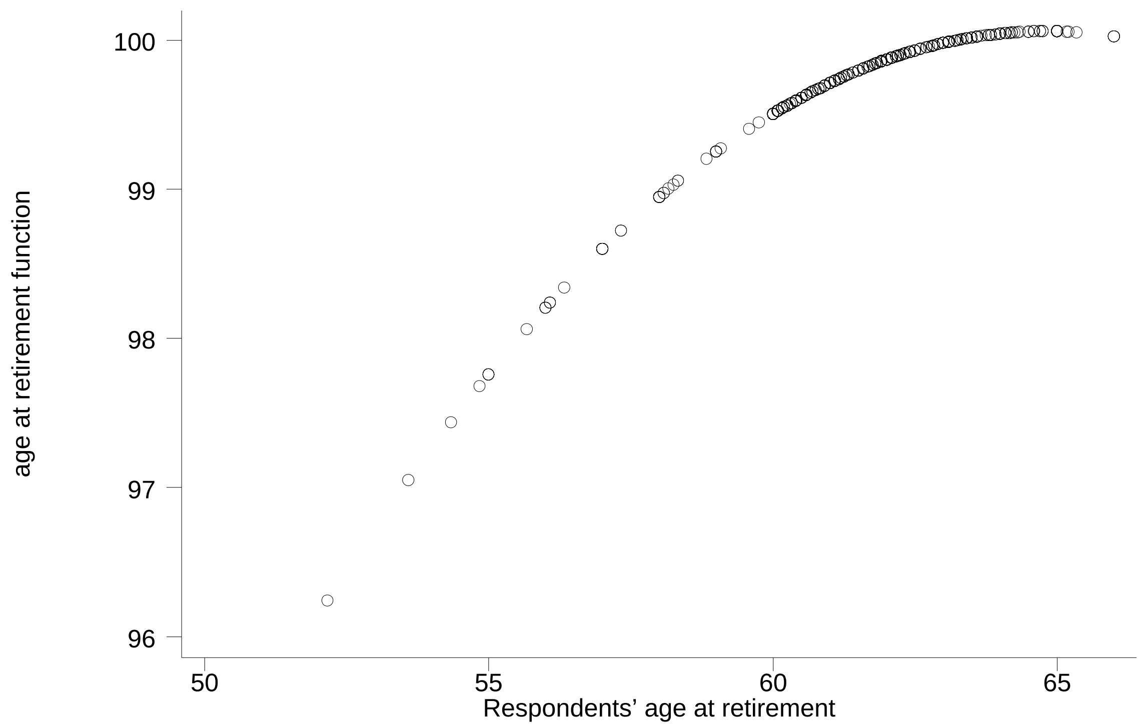

Figure 4.4: Age function

and the conversion factor (γ in equation (4.1)), that depart from personal characteristics. We expect that the probability of choosing a lump sum payment is a decreasing function of both these variables. Strikingly, our estimates go exactly in the opposite direction. However, when including company fixed effects (regression IV), the coefficient of the conversion factor takes the right sign and remains significant. As for the cut-off discount rate, it looses significance.

When adding a quadratic term for age at retirement[20] this variable becomes strongly significant: the probability of choosing a lump sum payment increases with retirement age (see the corresponding age function in Figure 4.4). This is in line with what we argued in Section 4.3.

A preliminary conclusion from these regressions is then the following: the role of personal characteristics on the choice between an annuity and a (partial) lump sum payment seems to be somewhat overshadowed by other components, namely company fixed effects

[20] We don't include it in Table 4.5 for space reasons.

and the conversion factor. Moreover, the cut-off discount rate seems to work in the wrong direction, suggesting that people make their choice disregarding our equation (4.3).

In their paper, Warner and Pleeter (2001) get point estimates of personal discount rates by estimating a simple probit model of lump-sum payment choice with the cut-off discount rate ρ^* as the only regressor. They assume that the (unobserved) personal discount rate ρ is a linear function of observed individual characteristics, denoted by X, and a random error term, ϵ, normally distributed with mean 0 and variance σ^2. Let β be a parameter vector, then

$$\rho = X\beta + \varepsilon \tag{4.4}$$

At ρ^* the present value of the annuity equals the lump sum payment. People choose the lump sum payment whenever the present value at their own discount rate is lower that the one at the cut-off discount rate, that is whenever $\rho > \rho^*$. Combining this with equation (4.4) gives

$$X\beta + \varepsilon > \rho^*. \tag{4.5}$$

The probability of choosing a lump sum payment is then

$$\begin{aligned} \Pr(LS) &= \Pr(X\beta + \varepsilon > \rho^*) \\ &= \Pr(X\beta - \rho^* > -\varepsilon) \\ &= \Pr(X\frac{\beta}{\sigma} - \frac{1}{\sigma}\rho^* > -\frac{\varepsilon}{\sigma}) \\ &= \Pr(X\delta - \alpha\rho^*) > \xi = \Phi(X\delta - \alpha\rho^*) \end{aligned} \tag{4.6}$$

where $\delta \equiv \frac{\beta}{\sigma}$, $\alpha \equiv \frac{1}{\sigma}$, $\xi \equiv -\frac{\varepsilon}{\sigma}$ and Φ is the standard normal distribution function. Equation (4.6) is an ordinary probit model because ξ is standard normal. Their estimates of discount rates are very high (up to 30%).

As Table 4.5 suggests, our data do not support such a model: the estimated coefficient for the cut-off discount rate has a positive sign for both specifications (with and without company fixed effects)[21]. Even if we apply the model to each singular company our finding

[21] An important aspect we have to consider when using maximum likelihood estimators is given by the properties of the distribution that we impose on our data. In binary choice models misspecification of the probability that $y_i = 1$ as a function of x_i may be responsible of inconsistent estimators. Usually, such misspecifications are motivated from the latent variable model and reflect non-normality or heteroskedasticity of the error term ϵ_i. We then perform a Lagrange multiplier test on normality and on heteroskedasticity. These tests are based on the first order conditions from a more general model that specifies the alternative hypothesis and check whether these are violated if we evaluate them at the parameter estimates of the current, restricted, model. A detailed description of how these test work

do not improve. In most companies, the impact of the cut–off rate is insignificant [22]. This is, to some degree, an artifact of the large heterogeneity of pension plans. Only for two companies out of nine the cut–off rate displays a negative sign: for them we find implicit discount factors of 4% (SIG) and 6% (Unilever), respectively, though in the latter case the estimate is not even significant. For all the remaining companies the cut-off rate keeps displaying a positive (and often insignificant) sign.

What Table 4.5 seems to suggest is that the conversion factor plays a more relevant role in the choice between an annuity or a (partial) lump sum payment. As already mentioned, in the specification without company fixed effects (regression III) the estimate of the conversion factor displays a positive and significant sign (as the one of the cut-off discount rate), but we observe that when controlling for company fixed effects (regression IV) the estimated coefficient of γ changes its sign from positive into negative, without loosing its significance. In other words, our data allow Equation (4.6) to be applied only to the conversion factors,so that individual preferences over the given options seem to be driven by the conversion factors rather than by the cut-off discount rates.

4.5 Conclusions

Most private pension companies in Switzerland offer a choice of options upon retirement: (Future) pensioners can advance or postpone retirement payments at a reduced or increased monthly benefit, respectively. In defined benefit plans, moreover, there is often a choice between a lump-sum capital payment upon retirement or a life-long annuity thereafter. The expected return for each of these options depends crucially on an agent's expected life-time, his/her marital status, as well as the presence of children under 18 years old (for which a substantial benefit is due).

In the first part of the chapter, we have constructed a simple life-cycle model to elicit theoretically the differences between the retirement options. Our model yields a number of testable conclusions. First, because (single and married) women live longer than single men on average, the former should choose an annuity, and the latter a lump-sum capital payment. Second, as expected lifetime is correlated with wealth, richer pensioners should opt for an annuity, and poorer for a one-time capital payment. Third, married men should

is provided by Verbeek (2000). We find that the normality assumption is not rejected, whereas the heteroskedasticity assumption is.

[22] It is crucial to do the analysis separately for the different companies, as the differences in pension schemes offered largely dominate any other effect.

prefer an annuity, especially if they have young children, or if they are married to a woman of the same or a younger age.

In the second part of the chapter, we have analyzed the choice between an annuity and a lump–sum capital payment upon retirement by using data provided in 2000 by nine pension funds in Switzerland. In contrast to most other field studies, individual's decisions involve very large amounts of money. The data clearly exhibits an evident "acquiescence bias": the large majority of respondents choose the standard option offered by the company. The probability of choosing the capital option shows a U–shaped dependence on total capital at retirement. This can be well explained by a combination of magnitude effects, insurance aspects, investment opportunities, and the desire to leave bequests. Moreover, the role of personal characteristics (such as gender, marital status, age at retirement, number of children) on the choice between an annuity and a (partial) lump sum payment seems to be somewhat overshadowed by other components, namely company fixed effects and the conversion factor. Indeed, the data does not support Warner and Pleeter's model (2001), as our main finding is that the conversion factor seems to play a more relevant role than the discount factor in explaining the individual's choice. This analysis seems to suggest that when taking financial decisions people choose on the basis of easy variables rather than of more complicated and sophisticated ones.

We believe that a deeper understanding of choice upon retirement and the related distributional consequences is of great interest to academic economists and to policy makers. While the asset side of fully funded pension plans is well explored and understood, the liability side still lacks a careful analysis. Advancing our knowledge of both sides will potentially lead to more equitable and efficient policies. In order to draw more solid conclusions our data base should be enlarged: many effects are masked by strong company and year-of-retirement effects. It will be absolutely necessary to expand the database along two dimensions. First, more companies in various sectors should be included: this would enable to better control for various specific effects. Second, several years should be included as well: often the generosity of offered early retirement options depended on the performance of the pension fund (which in theory should not).

Chapter 5

Saving and Habit Formation: Evidence from Dutch Panel Data

5.1 Introduction

The concept of habit formation relies on the idea that one's own past consumption might have an effect on the utility yielded by current consumption: for a given level of current consumption, a larger habit stock lowers utility. Habits were first introduced in the context of demand systems (Pollak and Wales, 1969; Phlips, 1972; Pollak, 1975). In the literature a distinction between two types of habits has been made: myopic (or naive) and rational. In the first case (Pollak, 1976), consumers are not aware of the effects that their current consumption decisions will have on their future marginal rates of substitution between goods and as a consequence their behavior may be time-inconsistent. In the second case (Lluch, 1974; Phlips, 1974; Spinnewyn, 1981; Muellbauer, 1986), consumers are aware of the habit forming effect of current consumption.

The presence of habit formation may provide an appealing (partial) explanation to a number of anomalous empirical findings contrasting some of the permanent income model's predictions, such as the "excess sensitivity" of aggregate consumption growth relative to current labor income growth[1], its "excess smoothness" relative to lagged labor income growth[2], the equity premium[3] puzzle and the risk-free rate[4] puzzle (Abel, 1990; Constantinides, 1990; Campbell and Cochrane, 1999; Seckin, 2000). Moreover, Carroll et al. (2000) show that if one allows for habit formation, then standard growth models can be reconciled with the empirical evidence suggesting that high growth leads to high saving, rather than the other way around. Fuhrer (2000) stresses the relevance of habits in a monetary-policy analysis, as the habit formation specification significantly improves the responses of both spending and inflation to monetary-policy actions.

[1] The permanent income model predicts that consumption changes should be orthogonal to predictable, or lagged, income changes. Yet, the correlation between consumption growth and lagged income growth seems to be one of the most robust features of aggregate data (Flavin, 1981; Blinder and Deaton, 1982; Campbell and Deaton, 1989; Attanasio and Weber, 1993).

[2] The permanent income model predicts that consumption growth should be more volatile than income growth if aggregate income growth has positive serial correlation. Yet, aggregate consumption growth seems to be much smoother than aggregate income growth (Deaton, 1987; Campbell and Deaton, 1989; Gali', 1991).

[3] Under time-separable utility, Mehra and Prescott (1985) could not found a plausible pair of subjective discount rate and relative risk aversion of the representative consumer to match the mean of the annual real rate of interest and of the equity premium in a US sample over a 90-year period. That is, stocks were not sufficiently riskier than Treasury bills to explain the spread of their returns.

[4] Weil (1989) found that in the same sample used by Mera and Prescott, although individuals like consumption to be very smooth and although the risk-free rate is very low, they still save enough that per-capita consumption grows rapidly.

In general, mixed conclusions about the strength of habit formation arise from past studies of time-nonseparable preferences based on aggregate consumption data. A number of studies using US aggregate monthly (Dunn and Singleton, 1986; Eichenbaum et al., 1988; Heaton, 1993) and quarterly (Muellbauer, 1988) consumption data display very little evidence of habits. However, other studies concerning US data (Ferson and Constantinides, 1991) and Japanese data (Braun et al., 1993) lead to a different conclusion.

One of the most common approaches in micro-econometric studies used to test the presence of habit formation has been the Euler equation approach. It focuses on a specific first-order condition implied by the optimization problem faced by a generic consumer, allowing the estimation of preference parameters[5]. In this strand of literature, Hotz, Kydland and Sedlacek (1988) examine whether intertemporally nonseparable utility functions are important in characterizing microdata on life-cycle labor supply behavior among white male workers in the U.S. They find empirical support for the hypothesis that agents' preferences directly depend upon past leisure decisions and for the relatively simple specification of nonseparable preferences proposed by Kydland and Prescott (1982). More recently, Meghir and Weber (1996) argue that the within marginal rate of substitution function can be used as a control when evaluation results obtained using the intertemporal Euler equation. They use a large sample of US households, drawn from twelve years of the Consumer Expenditure Survey to model the intertemporal and within period allocation of expenditure on food in the home, transport and services. They found no empirical support for intertemporal non-separability of preferences over food, transport and services. Similarly, Dynan (2000) finds no evidence of habit formation at the annual frequency. Her analysis on food consumption data from the Panel Study on Income Dynamics indicate that habit formation has at most an extremely limited influence on consumers' behavior. This finding is robust to a number of changes in the model's specification.

An alternative approach to the Euler equation is adopted by Alessie and Lusardi (1997), who derive closed-form solutions for consumption (and saving) under the assumption of CARA within period preferences.[6] Closed-form solutions for consumption and saving allow a better understanding of some of the issues concerning those variables, as they provide a rich specification that extends some of the previous results in the literature. A problem with the model of Alessie and Lusardi (1997) is that it does not preclude

[5] Whether estimates of structural parameters based on log-linearized Euler equations may be biased (Carroll, 2001) or not (Attanasio and Low, 2002) is still under debate.

[6] The study of Alessie and Lusardi (1997) does not contain an empirical part. In other words, they have not tested empirically the validity of their theoretical model.

negative consumption. A detailed description of Alessie and Lusardi's model is provided in Section 5.2 below.

Guariglia and Rossi (2001) generalize Weil's model (1993), based on hybrid non-expected utility preferences, by allowing for habit formation. They obtain a closed-form solution for consumption as a function of labor income and total resources, labor income risk and lagged consumption. They then derive an Euler equation of consumption changes[7], where current consumption changes depend on lagged changes and labor income risk. They estimate this Euler equation using data from the British Household Panel Survey for the period 1992-97 and they find that both labor income risk and past changes in consumption are important in determining current changes in consumption. In particular, for all the estimators they adopt (OLS, within groups, first-differenced GMM and System GMM) the lagged changes in consumption display a strong statistically significant negative effect on the current changes. This suggests that the utility function exhibits durability in Deaton's (1992) sense, rather than habit formation. It is worthwhile saying that Guariglia and Rossi's empirical model can be justified by the model by Alessie and Lusardi. In other words Guariglia and Rossi (2001) cannot infer empirically whether or not their complicated extension of Weil's model describes household behavior in a better way than the model of Alessie and Lusardi (1997).

In this chapter we estimate the models of Alessie and Lusardi (1997) and Guariglia and Rossi (2001). Our empirical models will be based on their closed-form solutions. In these closed form solutions saving is expressed as a function of lagged saving and other regressors. Alternatively, we could have used the Euler-equation approach (see e.g. Guariglia and Rossi (2001) and Dynan (2000)), but we will argue that this approach may yield spuriously negative estimates of the habit formation parameter because in surveys consumption is typically measured with considerable error. A second reason to use the closed form solution as a basis of the empirical model is that it embodies more information about the habit formation model than the Euler equation. Therefore, the closed form solution allows for a more powerful test of the validity of the habit formation model than the Euler equation approach. For example, contrary to Guariglia and Rossi (2001) we

[7] The Euler equation used by Guariglia and Rossi does not suffer from "death to Euler equation critique" of Carroll (1997). The basic idea behind this critique is that the estimation of log-linearized Euler equations using instrumental variables methods on cross-section household data should be abandoned as it does not yield any useful information. Guariglia and Rossi do not need to log-linearize the Euler equation, as they use a Constant Absolute Risk Aversion instantaneous utility function. However, as we said before, in the models of both Guariglia and Rossi (2001) and Alessie and Lusardi (1997) negative consumption is possible, which may sound strange.

are able to discriminate empirically between the models of Alessie and Lusardi (1997) and Guariglia and Rossi (2001). However, we have to qualify a bit the remark about he advantages of using the closed for solution in the empirical exercise: the closed form solution approach relies more heavily on proxy variables (e.g. we need a proxy for the expected discounted value of future income changes).

The remainder of the chapter is organized as follows. In the following Section 5.2 we describe the theoretical model. Section 5.3 illustrates our dataset, and Section 5.4 presents the corresponding empirical evidence. Section 5.5 concludes the chapter.

5.2 The theoretical model for habit formation and precautionary saving

In this section we describe the theoretical model we will use for empirical tests. We strictly refer to Alessie and Lusardi's (1997) model of habit formation, in its precautionary saving specification.

The reference model is the one by Caballero (1990), with a negative exponential utility function and an uncertain non-capital income, following a moving-average process with ψ_i representing the $i-$th MA coefficient. Hence:

$$E_t y_\tau - E_{t-1} y_\tau = \psi_{\tau-1} w_t \tag{5.1}$$

where $\psi_0 = 1$, $\sum_{\tau=t}^{\infty}(1+r)^{t-\tau}\psi_{\tau-t} < \infty$ and w_t is an i.i.d. innovation. Alessie and Lusardi extend Caballero's model by allowing for habit formation.

Assuming an infinite planning horizon, households choose current and future consumption in such a way that the following expected intertemporal non-additive utility function is maximized:

$$MaxE_t \sum_{\tau=t}^{\infty}(1+\rho)^{t-\tau}\left(-\frac{1}{\theta}e^{-\theta(c_\tau-\gamma c_{\tau-1})}\right) \tag{5.2}$$

subject to an intertemporal budget constraint:

$$\sum_{\tau=t}^{\infty}(1+r)^{t-\tau}c_\tau = (1+r)A_{t-1} + \sum_{\tau=t}^{\infty}(1+r)^{t-\tau}y_\tau \tag{5.3}$$

where A_{t-1} and $c_{t-1}$are given. E_t is the expectations operator, c_τ denotes consumption in period τ, y_τ is non-capital income, A_τ is non-human wealth, r is the real fixed interest rate and ρ is the rate of time preference. Current utility depends not only on current consumption, but also on consumption a period ago. Note that the infinite horizon over which the optimization occurs is a crucial assumption, which might not be realistic. However, this assumption allows us to rewrite the intertemporal budget constraint in the following way:

$$\sum_{\tau=t}^{\infty}(1+r)^{t-\tau}c_\tau = -\gamma c_{t-1} + \frac{(1+r-\gamma)}{(1+r)}\left[(1+r)A_{t-1} + \sum_{\tau=t}^{\infty}(1+r)^{t-\tau}y_\tau\right] \tag{5.4}$$

Given this equation, Alessie and Lusardi (1997) prove the following:

- The stochastic process of $c^*_\tau = c_\tau - \gamma c_{\tau-1}$ is a martingale with drift:

$$c^*_\tau = c^*_{\tau-1} + \Gamma_{\tau-1} + \upsilon_\tau \tag{5.5}$$

  where υ_τ denotes the innovation in consumption c^*_τ and $\Gamma_{\tau-1}$ is a measure of the effect of precautionary saving (see below).

- The relation between the consumption innovation υ_τ and the income innovation w_τ can be written as:

$$\upsilon_\tau = \psi^* w_\tau \tag{5.6}$$

  where $\psi^* = \left(1 - \frac{\gamma}{1+r}\right)\frac{r}{1+r}\sum_{i=0}^{\infty}\psi_i(1+r)^{-i}$.

  This means that if habit formation is not present ($\gamma = 0$), then the consumption innovation equals the annuity value of the contemporaneous innovation in income; when habit formation is there, the consumption innovation equals $\left(1 - \frac{\gamma}{1+r}\right)$ times the revision in permanent income. As a consequence, the larger the habit formation coefficient γ, the smaller ψ^*, and consequently, the less sensitive consumption is to income shocks.

- The consumption function implied by the maximization problem above has the following form:

$$c_t = \frac{\gamma}{1+r}c_{t-1} + \left(1 - \frac{\gamma}{1+r}\right)Y_{pt} - \frac{r}{1+r}\sum_{\tau=t+1}^{*\infty}(1+r)^{t-\tau}\sum_{\tau=t+1}^{\tau}\Gamma_{j-1} \tag{5.7}$$

  and $\Gamma_{j-1} = \frac{1}{\theta}\ln E_{j-1}\exp(-\theta\psi^* w_j)$ and $Y_{pt} = \frac{r}{1+r}\left[(1+r)A_{t-1} + \sum_{\tau=t}^{\infty}(1+r)^{t-\tau}y_\tau\right]$ denotes permanent income.

Equation (5.7) says that consumption depends on past consumption, permanent income and precautionary saving. Equation (5.7) is additive and precautionary saving depends on the properties of income risk. The parameter γ affects the relative importance of the three terms. In particular, the stronger the habit, the bigger the weight put on past consumption[8] and the lower the effect of income uncertainty on consumption.

If the model is written in terms of saving rather than consumption, the closed-form solution for saving takes the following form:

$$s_t = \gamma s_{t-1} + \frac{\gamma}{1+r}\Delta y_t - \left(1 - \frac{\gamma}{1+r}\right)\sum_{\tau=t}^{\infty}(1+r)^{t-\tau}E_t\Delta y_\tau + \frac{r}{1+r}\sum_{\tau=t+1}^{\infty}(1+r)^{t-\tau}\sum_{j=t+1}^{\tau}\Gamma_{j-1} \tag{5.8}$$

Similarly, saving depends on past saving, current and future income changes and properties of the income process. Once again, the importance of each component is a function of γ, that is of the strength of habit. In the case of no habits ($\gamma = 0$), the equation above is the standard "saving for a rainy day" equation; when there is habit formation ($\gamma > 0$), the stronger the habit, the lower the role of future income changes and of income uncertainty and the higher the one of past saving.

Guariglia and Rossi (2001) generalize Weil's model (1993), based on hybrid non-expected utility preferences, by allowing for habit formation. They obtain the following closed-form solution for consumption as a function of labor income and total resources, labor income risk and lagged consumption[9]:

$$c_t = \left(1 - \frac{\gamma}{1+r}\right)\left(1 - \frac{\delta - 1}{r}\right)Y_{pt} + \delta\frac{\gamma}{1+r}c_{t-1} + \varepsilon^* \tag{5.9}$$

where $\delta = \left(\frac{1+r}{1+\rho}\right)^{\frac{1}{\alpha}}$ (ρ denotes the rate of time preference) and ε^* ($\varepsilon^* < 0$) denotes the precautionary saving component which depends on, among other things, the variance of future income shocks and the habit formation parameter γ.[10] Notice that if $r = \rho$, then

[8] This is consistent with the fact that "*among its potentially important empirical implications, habit formation causes consumers to adjust slowly to shocks in permanent income*" (Dynan, 2000)

[9] See equation (10) of Guariglia and Rossi (2001)

[10] See equation (11) of Guariglia and Rossi (2001). The higher the variance of future income shocks, the more negative the precautionary saving term ε^* becomes. Like in the model of Alessie amd Lusardi (1997) Guariglia and Rossi's model predicts that the larger the habit formation coefficient γ, the less sensitive consumption is to income shocks (i.e precationary becomes less important).

$\delta = 1$. In that case model (5.9) is observationally equivalent to model (5.7). Model (5.9) implies the following saving equation:

$$s_t = \left(\delta - 1 + \gamma \tfrac{r+1-\delta}{1+r}\right)\left(\tfrac{1}{r}\Delta y_t + \tfrac{1+r}{r} s_{t-1}\right) - \\ - \left(1 - \tfrac{\gamma}{1+r}\right)\tfrac{1+r-\delta}{1+r}\left[\sum_{\tau=t}^{\infty}(1+r)^{t=\tau}(y_\tau - y_t)\right] + \tfrac{\gamma(1-\delta)}{r} c_{t-1} - \varepsilon^* \tag{5.10}$$

5.3 Description of the dataset

The empirical analysis is based on six waves of the CentER Savings Survey (CSS), drawn from 1993 to 1998. The CSS (formerly known as the VSB panel) is a panel survey started in 1993 and run every year. Until 1997, the CentER Savings Survey consisted of two samples. The first sample (REP) was intended to be representative of the Dutch population; it consists of some 2000 households in each wave, including refreshment samples compensating for panel attrition. The second sample (HIP) was representative of the top 10 percent of the income distribution and initially it contained some 900 households. In 1998 on most respondents of the second sample stopped, so that since that year on the CSS includes only the REP.

The CentER Savings Survey consists of five questionnaires: work and pensions, accommodation and mortgages, income and health, assets and liabilities, economic and psychological concepts. The questionnaires are sent to the respondents by modem, the respondents fill in the questionnaires at their home computers, and the answers are returned in the same way. This means that the questionnaires are self-administered and the respondents can answer the questionnaires at a time that is convenient for them.

For our purposes we focus mainly on the assets and liabilities questionnaire and the economic and psychological concepts. The former provides detailed information about forty asset and debt categories, both financial and real[11]. For most of these categories, respondents are first asked to indicate whether they own the type. If they do, they then have to answer a set of questions about the amounts and the precise nature of each asset/liability. Non-response is not an issue for the ownership questions, but it is for some of the questions on the amounts. We then adopt the same methodology by Alessie, Hochguertel and van Soest (2002), that is we have imputed the amounts for those who reported to be owners but did not provide an amount. The imputed values are based on amounts held in adjacent years and on regression models that relate observed amounts to

[11] A detailed description of these assets and liabilities is provided by Alessie, Hochguertel and van Soest (2002).

household characteristics. Prediction errors are taken into account by drawing errors from the estimated error term distribution in the regression models, where full account is taken of the covariance structure of the error terms over time. For all respondents these data have been aggregated into total income per component and total asset per component. On the basis of the various income components, total gross and total net income (on the respondent level) were computed also.

The economic and psychological concepts questionnaire represents a very rich set of questions about several topics, including personal characteristics, household income, expectations about future income, attitude towards saving and saving behavior, risk perception and risk aversion, expectations for the future and comparison with the current situation, planning of financial matters. For our purposes, we focus on a number of questions related to saving behavior.

Equation (5.8) is the starting point of our empirical analysis. We now provide a description of the variables used in the estimation procedure.

1. In the CSS, the dependent variable s_{it} (saving by household i in year t) can be measured as follows: first we use information about whether any money has been put aside in the previous 12 months by an individual. Then they are asked to indicate how much money their household has put aside in the same period. In our analysis we do not use limited dependent variable estimation technique for reasons explained in footnote 12. It is therefore important to deal with "no money put aside" answers (1907 cases out of the 6602 cases). We have further investigated these cases by crossing them with other informative variables in the questionnaire, in order to check for potential dissaving. In particular, we have considered the following question:

   "*Over the past 12 months, would you say the expenditures of your household were higher than the income of the household, about equal the income of the household, or lower than the income of the household?*"

   Second, we treat the dependent variable, s_{it}, as a continuous variable, represented by the amount of money put aside.[12] We built this variable as follows. For those

[12] Respondents report the amount of money put aside in classes. Out of this piece of information we have constructed a continuous variable by taking the mid-points for each class. Alternatively, we could have adopted a Limited Dependent Variable (LDV) technique (e.g. ordered probit) to obtain estimates of the parameters. However, our empirical habit formation model is obviously dynamic and allows for unobserved heterogeneity by including an individual effect. Obviously, some of the right hand

who have claimed to have put no money aside and whose expenditures were about equal the income of the household, it was clear that they have not saved and not dissaved either. We then have imputed zero as the amount of money put aside (1701 cases). For those who have claimed to have put no money aside and whose expenditures were higher than the income of the household, we have constructed a change in liquid financial wealth as a proxy of their dissaving and imputed that negative value as the amount of money put aside (141 observations). Finally, for those who have claimed to have put no money aside and whose expenditures were lower than the income of the household, we have constructed a change in liquid financial wealth as a proxy of their saving and imputed that (positive) value as the amount of money put aside, in order to overcome the contradiction (65 cases). In constructing the imputed variable mentioned above, we have used information about wealth. For each year, we have picked the most liquid categories for assets (checking accounts, savings arrangements, linked to a Postbank account, deposit books, savings or deposit accounts, savings certificates) net of the most liquid categories of liabilities (private loans and extended lines of credit) and then taken first differences. We have deleted extreme values in order to avoid including outliers in our imputations.

Obviously, we could have obtained an alternative saving measure by computing the first differences in (liquid) wealth. We will argue in the next section that using this measure may result in a spuriously negative estimate of the habit formation parameter

2. *Income change*: We build a variable ("realized income change") from the following set of questions:

   A. "*The total net income of your household consists of the income of all members of the household, after deduction of taxes and premiums for social insurance policies, taken as the sum total over the past 12 months. Compared to about one year ago, did the total net income of your household increase, remain about the same, or decrease?*"

   B. "*By what percentage (approximately) has the total net income of your household increased/decreased?*"

side variables (apart from lagged saving) may be correlated with the individual effect. Estimation of LDV models which allow for both state dependence and correlated unobserved heterogeneity, is notoriously difficult. Therefore, we abstain from such an approach and we make our dependent variable continuous.

We then transform percentages into amounts and use the latter specification in the empirical estimation.

3. *Expectation on income change*: Two time-horizon lenghts are considered, as we exploit the following questions:

   A1. "*Do you think the total net income of your household will increase, remain the same, or decrease in the next 12 months?*"

   A2. "*By what percentage do you think the total net income of your household will increase/decrease in the next 12 months?*"

   B1. "*Do you think the total net income of your household will increase, remain the same, or decrease in the next 5 years?*"

   B2. "*By what percentage do you think the total net income of your household will increase/decrease in the next 5 years?*"

   Two variables are then constructed: variable "Expected income change (next 12 mths)" refers to questions A1-A2, variable "Expected income change (next 5 years)" refers to questions B1-B2. Both variables are in amounts.

4. *Uncertainty on expected income change*: For each of the time-horizon lenghts described above, people are asked the following question:

   "*How certain do you feel about this income change?*"

   Individuals have to indicate their degree of uncertainty among four possibilities: very certain, rather certain, not very certain, not at all certain. Two categorical variables are then built: "... about inc. change (next 12 mths)" and "... about inc. change (next 5 years)" for 12 months expectations and for 5 years expectations, respectively.

5. *Background characteristics*: We add a number of individual characteristics, such as:

   - gender

   - level of education

   - age classes (in dummies)[13]

[13] In particular, age1 refers to age less than or equal 30, age 2 is age between 31 and 40, age 3 is age between 41 and 50, age 4 is age between 51 and 60, age 5 is age between 61 and 70, age 6 is age between 71 and 88.

- number of members in the household

- number of children in the household

- labor market status (in dummies)

Table 5.1 reports summary statistics for the variables just described and used in the empirical study. Most of them are self-explanatory. However, it is worth mentioning that gender is a categorical variable, which takes the value 1 for males and 2 for females. In the empirical estimations males are the reference group.

5.4 Empirical implementation and results

We take equation (5.8) as starting point of our analysis. We extend this model by allowing for demographic variables (e.g. family size, number of children, education level, age dummies) and for an unobserved individual effect α_i. Since the model contains a lagged endogenous variable (s_{it-1}) and an individual effect α_i, the standard within estimation technique yields inconsistent estimates. Procedures to estimate parameters of standard linear dynamic panel data models are discussed in numerous places. See, for example, Verbeek (2000, Section 10.4) for an accessible overview. To formulate the empirical model, two types of covariates are distinguished: $x_{it} = (x_{it}^1, x_{it}^2)'$. The empirical model has the following structure:

$$s_{it} = \gamma s_{it-1} + x_{it}'\theta + \alpha_i + \epsilon_{it} \tag{5.11}$$

where we make the following assumptions:

1. $\{x_{it}^1; t = 1, ..., T\}$ uncorrelated with $\{\epsilon_{it}; t = 1, ..., T\}$ (strict exogeneity)

2. $\{x_{it}^2; t = 1, ..., T\}$ uncorrelated with α_i and $\{\epsilon_{it}; t = 1, ..., T\}$

3. $\{\epsilon_{it}^1; t = 1, ..., T\}$ are mutually uncorrelated.

x_{it}^2 includes some time invariant regressors x_i^2 (e.g. gender, education level) which are assumed to be uncorrelated with the individual effects. Time invariant regressors that are not assumed to be uncorrelated with the individual effects are subsumed in the individual effects and not incorporated explicitly in the model. Thus an empty vector x_{it}^2

would correspond to the case where any correlation between individual effects and time invariant regressors is allowed for, as in a pure fixed effects model.[14]

Define, for $t = 3, \ldots, T$,

$$u_{it} = s_{it} - [x_{it}^{1\prime}\theta_1 + x_{it}^{2\prime}\theta_2 + s_{it-1}\gamma](= \alpha_i + \varepsilon_{it}) \tag{5.12}$$

and

$$\Delta u_{it} = u_{it} - u_{it-1}(= \epsilon_{it} - \epsilon_{it-1}) \tag{5.13}$$

The model assumptions imply the following moments

- $\mathrm{E}[\Delta \boldsymbol{x}_{it}^1 \Delta u_{it}] = 0;\ j = 1, 2;,\ \ t = 3, \ldots, T$ ((strict) exogeneity)
- $\mathrm{E}[y_{it-2} \Delta u_{it}] = 0;\ j = 1, 2;,\ \ t = 3, \ldots, T$ (lagged dependent variables)
- $\mathrm{E}[\boldsymbol{x}_{it}^2 u_{it}] = 0;\ j = 1, 2;\ t = 3, \ldots, T$ (exogeneity and uncorrelated with individual effect)

For a given specification, i.e., given choices of $\boldsymbol{x}_{it}^1$ and $\boldsymbol{x}_{it}^2$, these moments can be used for standard GMM estimation. According to Blundell et al. (2000), the following additional moment restrictions based upon a mean stationarity assumption can be used to improve efficiency:

$$E\ \Delta s_{it-1} u_{it} = 0 \tag{5.14}$$

The GMM estimation technique allows for any type of heteroskedasticity in ϵ_{it} . Sargan tests for overidentifying restrictions are used to test the validity of the moment restrictions. The assumption that the errors ϵ_{it} are uncorrelated error terms seems quite strong, but is common in this type of model. This assumption will be tested by checking for second order autocorrelation in the residuals in the differenced equations.[15]

Table 5.2 reports results for the estimation of coefficients in Equation (5.8) according to the following specification. x_{it}^1 includes the number of children in a household, the total number of a household components and precautionary saving terms, i.e. the degree of uncertainty about future both short and long run expected income changes.

[14] Following Hausman and Taylor (1981), coefficients on time invariant regressors correlated with individual effects could still be identified if some time varying regressors are uncorrelated to individual effects. We do not follow this approach since we do not see any natural candidates for this among our time varying regressors.

[15] To estimate the linear probability model, we use the DPD98 software as described in Arellano and Bond (1998).

x_{it}^2 includes realized income changes, both short and long run expectations about future income changes, gender, education levels and age dummies. We assume that the mean stationarity assumption holds.

The Sargan statistic does not indicate rejection of the moment conditions. Moreover, autocorrelation tests does not indicate rejection of assumption that $\{\epsilon_{it}^1; t = 1, ..., T\}$ are mutually uncorrelated.

The estimated habit formation parameter γ exhibits a positive and statistically significant sign. If we do not allow for unobserved heterogeneity, the estimate of the habit formation coefficient gets considerably larger: .41 (t-value 3.10) from .12: (t-value: 3.12). This result indicates that the unobserved heterogeneity may explain the positive raw correlation between saving and lagged saving. Our findings differs from Guariglia and Rossi's results, as they get a negative, strongly significant estimate for γ. As already mentioned in the introduction, they interpret this negative sign as an indicator of "durability" in Deaton's (1992) sense. Dynan (2000) estimates a similar Euler equation as Guariglia and Rossi (2001) but she considers food consumption instead of total consumption. Dynan also obtains a negative estimate for γ, albeit insignificant. Since food is a clearly non-durable good, her negative estimate cannot be explained by means of a durability argument.

However, another interpretation for the findings of Guariglia and Rossi (2001) and Dynan (2000) can be provided. Their estimates come from the Euler equation for consumption rather than from a closed form solution similar to our equation (5.11). The data at their disposal refers to consumption expenditures (rather than savings) which is presumably measured with considerable error. Such measurement errors are responsible for a strong spurious negative correlation between differences in current (Δc_{it}) and past consumption levels (Δc_{it-1}). As a consequence, the OLS estimate of the habit formation parameter γ is biased towards a "negative number": even if the true habit formation coefficient is greater than zero, the estimated coefficient is lower than zero and no standard attenuation bias towards zero occurs. Besides, although they also estimate the parameters of the Euler equation using GMM, their instruments may be too weak to compensate for the measurement error problem.[16] In other words, they may have found a spuriously negative habit formation coefficient.

Another feature to emphasize is that the estimate of the habit formation coefficient γ is close to the one for the realized income changes parameter[17]. This is in line with the

[16] Dynan (2000) reports partial R^2 of the first stage regressions which are quite low (around 0.015).
[17] The estimated γ is 0.118 and $\frac{\gamma}{1+r}$ is 0.178.

theoretical model: in Equation (5.8) the coefficients γ and $\frac{\gamma}{1+r}$ are virtually the same for small values of r.

As a proxy for expected income changes $\sum_{\tau=t}^{\infty}(1+r)^{t-\tau}E_t\Delta y_\tau$ we use variables "Expected income change (next 12 mths)" and "Expected income change (next 5 years)". Their coefficients should be negative $(-\left(1-\frac{\gamma}{1+r}\right))$ because of the "saving for a rainy day" argument (see Campbell (1987)). Obviously, this proxy is not perfect. The estimated coefficient of "Expected income change (next 5 years)" does not differ significantly from 0 (even after excluding "Expected income change (next 12 mths)"), whereas the estimated coefficient for "Expected income change (next 12 mths)" is very significant. Given the small estimated value of γ (0.12) and for reasonable values of the real interest rate, we would expect an estimated coefficient associated with "Expected income change (next 5 years)" of around -0.9. However, we obtain a much smaller value. This suggests either that people have a short time horizon or that they are liquidity constrained[18].

It is interesting to note that if we assume realized and expected income changes to be uncorrelated to the error terms (i.e. if variables "realized income change ", "Expected income change (next 12 mths)" and "Expected income change (next 5 years)" are included in x_{it}^1), then their coefficients become insignificant. However, in Table 5.2 the Sargan statistic does not indicate a rejection. Therefore we can assume that these three variables are orthogonal to the individual effect. Moreover, we have to stress that in model (5.11) ϵ_{it} should not be interpreted as a forecast error as in an Euler equation. If it were a forecast error we would not be allowed to include the three variables in x_{it}^2: we should have better used lagged values as instruments.

According to our estimation results, precautionary saving does not play an important role in saving behavior: the degree of uncertainty about both short and long run expected income changes is totally insignificant. A potential explanation is that the habit formation formation effect is rather strong: according to the theoretical model, in fact, the stronger the habit formation the weaker the precautionary saving. It is worth mentioning that if precautionary saving terms are included in x_{it}^2 (i.e. precautionary saving is assumed to be orthogonal to the individual effect), then their estimated coefficients get negative and significant. However, the Sargan statistic increases from 31.45 to 47.63, suggesting that this latter assumption is clearly rejected.

As for the demographic variables, we observe that females save significantly less than males. The role of education is rather hard to interpret: it seems that very high levels

[18]Liquidity constraints effectively shortens the time horizon as shown by e.g. Mariger (1987) or Zeldes (1989).

of education leads to bigger amounts of saving. Age classes are strongly significant, both separately (as dummies), with the only exception for the last class, and jointly[19]. The age coefficients suggests that, ceteris paribus, saving is a decreasing function of age. Family size and household composition do not play a relevant role in saving behavior. We also extended the model by including labor market status dummies. Obviously, these dummies are presumably correlated with the individual effect. Contrary to Meghir and Weber (1996), we do not find any significant effect of labor market variables.

One alternative to the model estimated in Table 5.2 is to exclude the time invariant education and gender variables completely. This would correspond to the pure fixed effects model, whose results are reported in Table 5.3. Results for this model are similar to those in Table 5.2.

It is worth noting that our definition of saving is based on information about money put aside and wealth. An alternative definition would be computing first differences in wealth. In the latter specification, our empirical model would take the following form

$$\Delta A_t = \gamma \Delta A_{t-1} + x'_{it}\theta + \alpha_i + \epsilon_{it} \tag{5.15}$$

Obviously, there exists a strong negative correlation between ΔA_t and ΔA_{t-1} because A_t is measured with considerable error. If we estimate Equation (5.15) by means of OLS we get a negative estimation of γ. Even by applying GMM, we obtain a negative estimate of γ: -.26 (t-value: 6.29) Moreover, this procedure would imply a loss of one year of observations[20]. As a consequence, we decided not to build (and work with) the saving measure with information about differences in wealth.

In order to investigate in more detail the fact that only short-run income expectations have a statistically significant impact on the amount of money put aside, we exploit a question related to family plans about possible future home purchase. Jackman and Sutton (1982) examine the effects of unanticipated interest rate changes on consumers' expenditures in a model with imperfect capital markets. They show that an increase in interest rates causes liquidity-constrained individuals to cut back their consumption by the full amount of the increase in their interest payments. In contrast, a fall in interest rates relaxes the liquidity constraint and does not lead to an immediate increase in consumption by the full amount of the fall in interest payments. For a better interpretation of our findings, it is important to say that consumers who anticipate the possibility of interest

[19]The p-value of the Wald test of the hypothesis that all 5 age coefficients are jointly equal to zero, is 0.014.

[20]The number of observations drops from 6390 to 3817.

rate changes may choose to hold some precautionary balances, and so partially offset the impact of interest rate rises, in that their optimal precautionary balances will be set at a level which will permit them to cushion the impact of sufficiently small interest rate rises. In order to investigate this issue, we select people who declared themselves being actively looking for another accommodation to buy. We then interact that piece of information with expectations about income changes over the next 12 months (variable "plexpdi1") and over the next 5 years (variable "plexpdi5"). It turns out (Table 5.4) that for the 12 month-horizon, thought not significant, the coefficients of income change expectation and of home purchase plans sum up to 0. This suggests that people have a longer horizon when thinking of long-term buying. However, long-run variables in the regression do not exhibit any significance.

Finally, we consider Guariglia and Rossi's extension of the model of Alessie and Lusardi (cf. equation (5.10)). This model implies that we should extend the empirical model (5.11) by adding lagged consumption to the right hand side:

$$s_{it} = \gamma s_{it-1} + x_{it}'\theta + \zeta c_{it-1} + \alpha_i + \epsilon_{it} \tag{5.16}$$

We estimate the parameters of equation (5.16) by means of GMM (see Table 5.5). We obtain basically the same results as before, so that we can conclude that Guariglia and Rossi's habit formation model is similar to Alessie and Lusardi's. However, it is important to point out that ζ turns out to be significantly different from 0, indicating that the rate of time preference ρ is not equal to the real interest rate r.

5.5 Conclusions

In this chapter we closely relate to Alessie and Lusardi's (1997) model of consumption with habit formation as we estimate a model which is based on their closed-form solution. Our empirical results show evidence in favor of habit formation. This conclusion is not in line with some earlier literature. Dynan (2000) and Guariglia and Rossi (2001) find negative estimates of the habit formation coefficient. Their estimates come from the Euler equation for consumption rather than from a closed form solution. We argue that the data they use in their analysis refers to consumption expenditures (rather than savings) which is presumably measured with considerable error. Such measurement errors may be responsible for a strong spurious negative correlation between differences in current (Δc_{it}) and past consumption levels (Δc_{it-1}). As a consequence, the OLS estimate of the habit formation parameter γ is biased towards a "negative number". Moreover, although they also estimate the parameters of the Euler equation using GMM, their instruments may be too weak to compensate for the measurement error problem. Our impression is that the measurement error in consumption might be an argument against the use of the Euler equation approach to estimate the preference parameters in habit formation models. However, more econometric research (e.g. using Monte Carlo studies) is needed in order to evaluate the statistical properties of GMM methods in estimating those dynamic panel data models where the correlation between the dependent variable and the lagged dependent variable is negative because of the presence of (transitory) measurement errors.

We should note that the habit formation model is not fully accepted by the data. We find evidence in favor of a short planning horizon and liquidity constraints. More theoretical research seems to be needed in order to investigate the joint impact of liquidity constraints and habit formation.

When investigating Guariglia and Rossi's extension of the habit formation model of Alessie and Lusardi's we get similar estimation results. However, we find support for the fact that the rate of time preference ρ is not equal to the real interest rate r. This means that the two versions of the habit formation model are not observationally equivalent.

Finally, up to this point we have not looked at preference interdependence (Kapteyn et al., 1997), which might (partially) explain the significance of the habit formation coefficient we have found. This should be on the agenda for future research.

Table 5.1: *Descriptive statistics*

Variable	**Mean**	**Std Dev**	**Min**	**Max**
Saving	7993.3	14151.32	-48042	150000
Lagged saving	8046.6	13805.29	-42500	150000
Gender	1.1384	.34543	1	2
Intermediate/low education	.11311	.31676	0	1
Intermediate/high education	.11250	.31601	0	1
Vocational education, level 1	.11147	.31475	0	1
Vocational education, level 2	.12436	.33003	0	1
Vocational education, level 3	.30190	.45913	0	1
University education	.18675	.38975	0	1
Age1	.03375	.18060	0	1
Age2	.18040	.38456	0	1
Age3	.27347	.44579	0	1
Age4	.21170	.40855	0	1
Age5	.20434	.40326	0	1
Number of household members	2.5003	1.2722	1	9
Number of children	.70669	1.0722	0	7
Realized income change	655.20	11553.47	-105000	462000
Expected income change (next 12 mths)	638.44	79104.90	-330000	5500000
Expected income change (next 5 years)	845.02	10826.15	-210000	178500
Very certain about inc. ch. (next 12 mths)	.25279	.43464	0	1
Rather certain about inc. ch. (next 12 mths)	.65009	.47697	0	1
Not very certain about inc. ch. (next 12 mths)	.08530	.27935	0	1
Not at all certain about inc. ch. (next 12 mths)	.01180	.10803	0	1
Very certain about inc. ch. (next 5 years)	.13548	.34227	0	1
Rather certain about inc. ch. (next 5 years)	.65474	.47550	0	1
Not very certain about inc. ch. (next 5 years)	.18593	.38909	0	1
Not at all certain about inc. ch. (next 5 years)	.02291	.14963	0	1
Working	.41862	.49338	0	1
Retired	.24577	.43059	0	1
Disabled	.03481	.18333	0	1
Self-employed	.19674	.39757	0	1
Other	.10238	.30319	0	1

Table 5.2: *The basic habit formation model: estimation results*

Parameter	**Coefficient**	**Std Err**	**t-value**
Constant	7776.29	3329.83	2.335
Lagged saving	.118652	.037997	3.122
Gender	-2407.4	964.230	2.496
Intermediate/low education	230.834	980.672	.235
Intermediate/high education	1040.04	1017.00	1.022
Vocational education, level 1	-1332.5	926.223	1.438
Vocational education, level 2	261.847	912.593	.286
Vocational education, level 3	3147.76	970.723	3.242
University education	4666.63	1150.01	4.057
Age1	3256.78	1453.89	2.246
Age2	2566.60	1024.22	2.505
Age3	2102.57	1114.73	1.886
Age4	2326.55	714.559	3.255
Age5	992.959	576.081	1.723
Realized income change	.178989	.030716	5.827
Expected Income change (next 12 mths)	-.00191	.000401	4.771
Expected Income change (next 5 years)	-.01619	.022757	.711
Number of household members	-941.70	1340.96	.702
Number of children	1288.79	1476.76	.872
Rather certain about inc. ch. (next 12 mths)	-535.01	472.856	1.131
Not very certain about inc. ch. (next 12 mths)	54.2176	772.060	.070
Not at all certain about inc. ch. (next 12 mths)	439.567	1241.42	.354
Rather certain about inc. ch. (next 5 years)	-393.32	658.789	.597
Not very certain about inc. ch. (next 5 years)	-633.12	834.009	.759
Not at all certain about inc. ch. (next 5 years)	-1540.6	1920.67	.802
Wald test of joint significance	313.004 df=24 p=.000		
Sargan test	31.453 df=22 p=.087		
Test for first-order serial correlation	-4.881 [988] p=.000		
Test for second-order serial correlation	.452 [567] p=.651		

Table 5.3: *Habit formation model without time invariant variables: estimation results*

Parameter	**Coefficient**	**Std Err**	**t-value**
Constant	5459.02	2353.79	2.319
Lagged saving	.1153	.039517	2.920
Age1	3394.67	1479.87	2.293
Age2	2549.49	1063.59	2.397
Age3	2377.28	1165.48	2.039
Age4	2609.15	742.442	3.514
Age5	1083.96	599.862	1.807
Realized income change	.1786	.0307	5.812
Expected Income change (next 12 mths)	-.002	.0003	5.600
Expected Income change (next 5 years)	-.001	.0230	.067
Number of household members	-362.10	1381.80	.262
Number of children	1002.86	1525.70	.657
Rather certain about inc. ch. (next 12 mths)	-375.89	531.947	.706
Not very certain about inc. ch. (next 12 mths)	345.524	810.004	.426
Not at all certain about inc. ch. (next 12 mths)	658.380	1271.80	.517
Rather certain about inc. ch. (next 5 years)	-420.92	664.681	.633
Not very certain about inc. ch. (next 5 years)	-595.09	839.370	.708
Not at all certain about inc. ch. (next 5 years)	-1853.7	1943.39	.953
Wald test of joint significance	169.89 df=17 p=.000		
Sargan test	19.709 df=15 p=.183		
Test for first-order serial correlation	-4.802 [988] p=.000		
Test for second-order serial correlation	.452 [567] p=.651		

Table 5.4: *Habit formation and housing purchase in the future*

Parameter	**Coefficient**	**Std Err**	**t-value**
Constant	8503.58	3212.24	2.647
Lagged saving	.124221	.0370	3.348
Gender	-2463.9	929.766	2.650
Intermediate/low education	375.085	973.212	.385
Intermediate/high education	1102.54	1008.20	1.093
Vocational education, level 1	-1255.7	923.746	1.359
Vocational education, level 2	385.074	905.632	.425
Vocational education, level 3	3206.79	966.660	3.317
University education	4624.34	1128.42	4.098
Age1	3491.18	1451.33	2.405
Age2	2338.28	954.954	2.448
Age3	1971.18	1039.81	1.895
Age4	2152.22	696.748	3.088
Age5	979.325	570.471	1.716
Realized income change	.146961	.038489	3.818
Expected Income change (next 12 mths)	-.08550	.055598	1.537
Expected Income change (next 5 years)	-.00782	.028538	-.274
Plexpdi1 (a)	.084632	.055620	1.521
Plexpdi5 (b)	.016076	.054592	.294
Number of household members	-1422.2	1282.22	1.109
Number of children	2007.10	1393.24	1.440
Rather certain about inc. ch. (next 12 mths)	-550.68	468.422	1.175
Not very certain about inc. ch. (next 12 mths)	95.0793	766.496	.124
Not at all certain about inc. ch. (next 12 mths)	464.041	1195.19	.388
Rather certain about inc. ch. (next 5 years)	-434.25	651.601	.666
Not very certain about inc. ch. (next 5 years)	-655.20	828.411	.790
Not at all certain about inc. ch. (next 5 years)	-1785.8	1866.72	-.956
Wald test of joint significance	381.234	df=26	p=.000
Sargan test	34.302	df=24	p=.000
Wald test of joint significance for (a) and (b)	26.404	df=2	p=.000
Test for first-order serial correlation	-4.936	[988]	p=.000
Test for second-order serial correlation	.584	[567]	p=.559

Table 5.5: *The habit formation model of Guariglia and Rossi*

Parameter	**Coefficient**	**Std Err**	**t-value**
Constant	7112.06	3792.86	1.875
Lagged saving	.13981	.03613	3.869
Gender	-1515.9	1034.46	1.465
Intermediate/low education	123.319	946.919	.130
Intermediate/high education	305.809	988.474	.309
Vocational education, level 1	-476.16	876.690	.543
Vocational education, level 2	519.959	907.521	.572
Vocational education, level 3	1475.94	964.640	1.530
University education	2257.54	1200.05	1.881
Age1	3450.42	1314.18	2.625
Age2	2267.16	1039.48	2.181
Age3	1435.29	1116.98	1.284
Age4	1309.64	743.275	1.761
Age5	479.581	624.553	.767
Realized income change	.16630	.02941	5.653
Expected income change (next 12 mths)	-.0021	.00029	7.334
Expected income change (next 5 years)	-.0013	.02432	.055
Lagged consumption	.09431	.01262	7.468
Number of household members	-3303.00	1716.69	1.924
Number of children	3525.082	1739.19	2.026
Rather certain about inc. ch. (next 12 mths)	-367.388	482.363	.761
Not very certain about inc. ch. (next 12 mths)	-107.210	754.361	.142
Not at all certain about inc. ch. (next 12 mths)	870.542	1259.65	.691
Rather certain about inc. ch. (next 5 years)	-507.007	657.410	.771
Not very certain about inc. ch. (next 5 years)	-331.132	827.900	.399
Not at all certain about inc. ch. (next 5 years)	-2177.36	1955.21	1.113
Wald test of joint significance	386.695 df=25 p=.000		
Sargan test	35.660 df=23 p=.045		
Test for first-order serial correlation	-4.892 [988] p=.000		
Test for second-order serial correlation	-.085 [567] p=.932		

Bibliography

Abel, A. (1990), "Asset Prices under Habit Formation and Catching Up with the Jones, *American Economic Review*, 40, 38-42.

Ainslie, G. and Varda Haendel (1983) "The Motives of the Will", in Gottheil E. et al. (eds.) *Etiologic Aspects of Alcohol and Drug Abuse*, Springfield, IL, Charles C. Thomas, 119-140.

Alessie, R., Hochguertel, S. and van Soest, A. (2002), "Household Portfolios in the Netherlands", in Guiso, Haliassos and Jappelli (eds.), *Household Portfolios*, Cambridge, MA: MIT Press.

Alessie, R. and Lusardi, A. (1997), "Consumption, Saving and Habit Formation", *Economics Letters*, 55, 103-108.

Arellano, M. and Bond, S. (1998), "Dynamic Panel Data Estimation Using DPD98 for GAUSS: A Guide for Users", mimeo.

Arrondel, L. (2000), "Risk Management, Liquidity Constraints and Wealth Accumulation Behavior in France", mimeo.

Attanasio, O. and Weber, G. (1993), "Consumption Growth, the Interest Rate and Aggregation", *Review of Economic Studies*, 60, 631-649.

Attanasio, O. and Low, K. (2002), "Estimating Euler Equations", NBER Working Paper n. t0253.

Barsky, R.B., Juster, F.T., Kimball, M.S., Shapiro, M.D. (1997), "Preference Parameters and Behavioral Heterogeneity: an Experimental Approach in the Health and Retirement Study", *The Quarterly Journal of Economics 112,* 729-758.

Bernartzi, S. and Thaler, R. (2001), "Naive Diversification Strategies in Defined Contribution Saving Plans", *American Economic Review* 91, 79-98.

Blinder, A. and Deaton, A. (1985), "The Time Series Consumption Function Revisited", *Brooking Papers on Economic Activity*, 465-521.

Blundell, R., S. Bond and F. Windmeijer (2000), "Estimation in Dynamic Panel Data Models: Improving on the Performance of the Standard GMM Estimators," in B. Baltagi (ed.), *Nonstationary Panels, Panel Cointegration, and Dynamic Panels.* Advances in Econometrics, 15, JAI Press, Amsterdam.

Braun, P., Constantinides, G. and Ferson, W. (1993), "Time Nonseparability of Aggregate Consumption: International Evidence", *European Economic Review*, 37, 897-920.

Caballero, R. (1990), "Consumption Puzzles and Precautionary Savings", *Journal of Monetary Economics*, 25, 113-136.

Campbell, J. (1987), "Does Saving Anticipate Declining Labor Income? An Alternative Test of the Permanent Income Hypothesis", *Econometrica*, 55 (6), 1249-1273.

Campbell, J. and Cochrane, J. (1999), "By Force of Habit: A Consumption-Based Explanation of Aggregate Stock Market Behavior", *Journal of Political Economy*, 107, 205-51.

Campbell, J. and Deaton, A. (1989), "Why is Consumption So Smooth?", *Review of Economic Studies*, 56, 357-374.

Carroll, C. (1997), "Death to the Log-Linearized Consumption Euler Equation! (And Very Poor Health to the Second-Order Approximation)", *Advances in Macroeconomics*, 1,

Carroll, C. and Weil, D. (1994), "Saving and Growth: A Reinterpretation", *Carnegie-Rochester Conference Series on Public Policy*, 40, 133-192.

Carroll, C. and Samwick, A. (1997), "The Nature of Precautionary Wealth", *Journal of Monetary Economics*, 40, 41-71.

Carroll, C.D. (2000), "Solving Consumption Models with Multiplicative Habits", *Economics Letters*, 68 (1), 67-77.

Carroll, C., Overland, J. and Weil, D. (2000), "Saving and Growth with Habit Formation", *American Economic Review*, 90 (3), 341-355.

Constantinides, G. (1990), "Habit Formation: A Resolution of the Equity Premium Puzzle", *Journal of Political Economy*, 98, 519-543.

Cooper, I.A. and Kaplanis, E. (1994), "Home Bias in Equity Portfolios, Inflation Hedging, and International Capital Market Equilibrium", *The Review of Financial Studies* 7 n. 1, 45-60.

Deaton, A. (1987), "Life-Cycle Models of Consumption: Is the Evidence Consistent with the Theory?", in Bewley, T. (ed.), *Advances in Econometrics, Fifth World Congress*, 2, Cambridge, Cambridge University Press, 121-148.

Deaton, A. (1991) "Saving and Liquidity Contraints", *Econometrica*, 59, 1221-1248.

Deaton, A. (1992), *Understanding Consumption*, Clarendon Press, Oxford.

Debreu, G. (1959), *Theory of Value: An Axiomatic Analysis of Economic Equilibrium*, New York, Wiley.

Donkers, B. and van Soest, A. (1999), "Subjective Measures of Household Preferences and Financial Decisions", *Journal of Economic Psychology*, 20, 613-642.

Donkers, B., Melenberg, B. and van Soest, A. (1999), "Estimating Risk Attitudes Using Lotteries: A Large Sample Approach", *CentER Discussion Paper*, n. 9912, Tilburg University.

Dunn, K. and Singleton, K. (1986), "Modeling the Term Structure of Interest Rates under Non-separable Utility and Durability of Goods", *Journal of Financial Economics*, 17, 27-55.

Dynan, K. (2000), "Habit Formation in Consumer Preferences: Evidence from Panel Data", *American Economic Review*, 90 (3), 391-406.

Edwards, S. (1995), "Why are Saving Rates so Different Across Countries? An International Comparative Analysis", *NBER Working Paper 5097.*

Eichenbaum, M., Hansen, L. and Singletone, K. (1988), "A Time Series Analysis of Representative Agent Models of Consumption and Leisure under Uncertainty", *Quarterly Journal of Economics*, 103, 51-78.

Epstein, L. and Zin, S. (1989), "Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: A Theoretical Framework", *Econometrica,* 57, 937-969.

Epstein, L. and Zin, S. (1991), "Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: An Empirical Analysis", *Journal of Political Economy,* 99, 263-286.

Ferson, W. and Constatinides, G. (1991), "Habit Persistence and Durability in Aggregate Consumption: Empirical Tests", *Journal of Financial Economics*, 29, 199-240.

Flavin, M. (1981), "The Adjustment of Consumption to Changing Expectations about Future Income", *Journal of Political Economy*, 89, 974-1009.

French, K. and Poterba, J. (1990), "Japanese and US Cross-border Common Stock Investments", *Journal of the Japanese and International Economies* 4, 476-493.

French, K. and Poterba, J. (1991), "Investor Diversification and International Equity Markets", *American Economic Review* 81 , 222-226.

Fuhrer, J. (2000), "Habit Formation in Concumtpion and Its Implications for Monetary-Policy Models", *American Economic Review*, 90 (3), 367-390.

Gali', J. (1990), "Budget constraints and Time Series Evidence on Consumption", *American Economic Review*, 81, 1238-1253.

Glassman, D. and Riddick, L. (2001), "What Causes Home Asset Bias and How Should It Be Measured?", *Journal of Empirical Finance* 8, 35-54.

Gollier, C. (2002), "The Economics of Risk and Time", MIT Press, forthcoming.

Gourinchas, P. and Parker, J. (2001) "The Empirical Importance of Precautionary Saving", *American Economic Review*, 91(2), 406-412.

Guariglia, A. and Rossi, M. (2001), "Consumption, Habit Formation and Precautionary saving: Evidence from the British Household Panel Survey", mimeo.

Haliassos, M. and Hassapis, C. (2000), "Equity Culture and Household Behavior", Mimeo, University of Cyprus.

Hall, R. (1988), "Intertemporal Substitution in Consumption", *Journal of Political Economy,* 96, 339-357.

Hausman, J. (1979), "Individual Discount Rates and the Purchase and Utilization of Energy-using Durables", *Bell Journal of Economics,* 10, 33-54.

Hausman, J. and Taylor, W. (1981), "Panel Data and Unobservable Individual Effects", *Econometrica*, 49, 1377-1398.

Heaton, J. (1993), "The Interaction Between Time-Nonseparable Preferences and Time Aggregation", *Econometrica*, 61, 353-85.

Henderson, J. and Quandt, R. (1980), *Microeconomic Theory: A Mathematical Approach,* New York, McGraw-Hill.

Hotz, J., Kydland, F. and Sedlacek, G. (1988), "Intertemporal Preferences and Labor Supply", *Econometrica*, 56, 335-360.

Hurd, M. (1998) "An Analysis of the Choice to Cash Out Pension Rights at Job Change or Retirement", RAND Discussion Paper.

Hurd, M. (1999) "Anchoring and Acquiescence Bias in Measuring Assets in Household Surveys", *Journal of Risk and Uncertainty*, 19 (1-3): 111–136.

Jackman, R. and Sutton, J. (1982), "Imperfect Capital Markets and the Monetarist Black Box: Liquidity Contraints, Inflation and the Asymmetric Effects of Interest Rate Policy", *The Economic Journal*, 92, 108-128.

Jermann, U.J. (2002), "International Portfolio Diversification and Endogenous Labor Supply Choice", *European Economic Review* 46, 507-522.

Kahneman, D., Slovic P. and Tversky, A. (eds.) (1982), *Judgment Under Uncertainty: Heuristics and Biases,* Cambridge, Cambridge University Press.

Kapteyn, A., van de Geer, S., van de Stadt, H. and Wansbeek, T. (1997), "Interdependent Preferences: An Econometric Analysis", *Journal of Applied Econometrics*, 10, 665-686.

Kooreman, P. (1995), "Individual Discounting and the Purchase of Durables with Random Lifetimes", *Economics Letters,* 45, 29-32.

Kurz, M., Spiegelman, R. and West, R. (1973), "The Experimental Horizon and the Rate of Time Preference for the Seattle and Denver Income Maintenance Experiments: A Preliminary Study", Menlo Park, Calif.: SRI Internat.Res. Memorandum no.21.

Kydland, F. and Prescott, E. (1982), "Time to Build and Aggregate Fluctuations", *Econometrica*, 50, 1345-1370.

Laibson, D. (1997), "Hyperbolic Discounting and Time Preference Heterogeneity", Harvard University, mimeo.

Lawrance, E. (1991), "Poverty and the Rate of Time Preference: Evidence from Panel Data", *Journal of Political Economy,* 99, 54-77.

Lluch, C. (1974), "Expenditure, Savings and Habit Formation", *International Economic Review*, 15, 786-797.

Loewenstein, G. (1987) "Anticipation and the Valuation of Delayed Consumption", *Economic Journal*, 97, 666-684.

Loewenstein, G. and Thaler, R. (1989) , "Anomalies in Intertemporal Choice", *Journal of Economic Perspectives,* 3, 181-193.

Luce, R. and Raiffa, H. (1957), *Games and Decisions*, New York, Wiley.

Mariger, R. (1987), "A Life-Cycle Consumption Model with Liquidity Contraints: Theory and Empirical Results", *Econometrica*, 55 (3), 533-557.

Meghir, C. and Weber, G. (1996), "Intertemporal Nonseparability or Borrowing Restrictions? A Disaggregate Analysis using a U.S. Consumption Panel", *Econometrica*, 64, 1151-1181.

Mehra R. and Prescott, E. (1985), "The Equity Premium: A Puzzle", *Journal of Monetary Economics*, 15, 145-161.

Muellbauer, J. (1988), "Habits, Rationality and Myopia in the Life Cycle Consumption Function", *Annales d'Economie et de Statistique*, 9, 47-70.

Muller, D. (1989), *Public Choice 2*, 2nd ed. Cambridge, Cambridge University Press.

Phlips, L. (1972), "A Dynamic Version of the Linear Expenditure Model", *Review of Economics and Statistics*, 54, 450-458.

Phlips, L. (1974), *Applied Consumption Analysis*, Amsterdam, North-Holland.

Pollak, R. and Wales, T. (1969), "Estimation of the Linear Expenditure System", *Econometrica*, 37, 611-628.

Pollak, R. (1970), "Habit Formation and Dynamic Demand Function", *Journal of Political Economy*, , .

Pollak, R. (1976), "Habit Formation and Long-Run Utility Functions", *Journal of Economic Theory*", , .

Raiffa, H. (1968), *Decision Analysis: Introductory Lectures on Choices Under Uncertainty*, Reading, MA, Addison-Wesley.

Samwick, A. (1998) "Discount Rate Heterogeneity and Social Security Reform", *Journal of Development Economics*, 57(1): 117–146.

Seckin, A. (2000), "Consumption with Habit Formation", Cirano Scientific Series, 39.

Shane, F., Loewenstein, G. and O'Donoghue, T. (2002), "Time Discounting: A Critical Review", *Journal of Economic Literature*, 40(2), 351-401.

Simon, H. (1955), "A Behavioral Model of Rational Choice", *Quarterly Journal of Economics*, 69, 99-118.

Spinnewijn, F. (1981), "Rational Habit Formation", *European Economic Review*, 15, 91-109.

Tesar, L. and Werner, I.M. (1992), "Home Bias and the Globalization of Securities Markets", *NBER Working Paper* 4218.

Tesar, L. and Werner, I.M. (1994), "International Equity Transactions and US Portfolio Choice", in Frankel, J.A. (ed.) *The Internationalization of Equity Markets,* Univ. of Chicago Press, Chicago, 185-227.

Tesar, L. and Werner, I.M. (1995), "Home Bias and High Turn-over", *Journal of International Money and Finance* 14, 467-492.

Thaler, R. (1981) "Some Empirical Evidence on Dynamic Inconsistency", *Economic Letters*, 8, 201-207.

Thaler, R. and Shefrin, H. (1981), "An Economic Theory of Self-Control", *Journal of Political Economy* 89, 392-406.

Thomas, W. and Ward, W. (1979), "Time Orientation, Optimism and Quasi-Economic Behavior", *Working Paper*, Stanford University.

Verbeek, M. (2000), *A Guide to Modern Econometrics*, Wiley & Son, New York.

Vissing-Jorgensen, A. (1999), "Towards and Explanation of Household Portfolio Choice Heterogeneity: Nonfinancial Income and Participation Cost Structures", mimeo, University of Chicago.

von Neumann, J. and Morgenstern, O. (1953), *Theory of Games and Economic Behavior*, 3rd ed. Princeton, NJ, Princeton University Press.

Warner J. and Pletter, S. (2001) “The Personal Discount Rate: Evidence from Military Downsizing Programs”, *American Economic Review*, 91(1): 33–53.

Weil, P. (1989), “The Equity Premium Puzzle and the Risk-Free Rate Puzzle”, *Journal of Monetary Economics*, 24, 401-421.

Zeldes, S. (1989), “Consumption and Liquidity Constraints: An Empirical Investigation”, *Journal of Political Economy*, 97, 305-346.

Appendix A

Utility functions with habit formation

We report the derivation of the utility functions for both First order Markov habits and for Moving Average habits.

A.1 First order Markov habits

This is the simplest case. We specify z_t as a function of c_{t-1}. An obvious specification for the intratemporal utility function would then be $v(c_t - \theta z_t)$. Of course we may wish to consider transformations of c_t, e.g. its logarithm. Let $h(.)$ be a monotonically increasing function, then a fairly general specification for the intratemporal utility function would be $v(h(c_t) - \theta h(z_t))$.

Choosing the logarithm for the transformation function h, the intertemporal utility function is then:

$$\overline{u} = \sum_{\tau=l}^{L} (1+\delta)^{l-\tau} \frac{1}{1-\rho} (\frac{c_\tau^i}{(z_\tau^i)^\theta})^{1-\rho} \tag{A.1}$$

where $z_\tau^i \equiv c_{\tau-1}^i$ for $\tau = l, ..., L,$ and $z_l^i \equiv c_0$. We can write

$$\frac{c_\tau^i}{(z_\tau^i)^\theta} = \frac{c_l^i A_i^{(\tau-l)}}{(c_l^i)^\theta A_i^{(\tau-l-1)\theta}} = (c_l^i)^{1-\theta} A_i^{(\tau-l)(1-\theta)+\theta} = (c_l^i)^{1-\theta} A_i^\theta A_i^{(\tau-l)(1-\theta)} \tag{A.2}$$

Hence,

$$\begin{aligned}\overline{u} &= \frac{1}{1-\rho}(\frac{c_l^i}{c_0^\theta})^{1-\rho} + \frac{1}{1-\rho}(c_l^i)^{(1-\theta)(1-\rho)}A_i^{\theta(1-\rho)}\sum_{\tau=l+1}^{L}(1+\delta)^{l-\tau}A_i^{(1-\theta)(1-\rho)(\tau-l)} \\ &= \frac{1}{1-\rho}(\frac{c_l^i}{c_0^\theta})^{1-\rho} + \frac{1}{1-\rho}(c_l^i)^{(1-\theta)(1-\rho)}A_i^{\theta(1-\rho)}\frac{\Psi_i - \Psi_i^{L-l+1}}{1-\Psi_i} \qquad (A.3)\end{aligned}$$

with $\Psi_i \equiv \frac{A_i^{(1-\theta)(1-\rho)}}{1+\delta}$

A.2 Moving Average habits

In this case we let habits evolve according to $h(z_t) = \beta h(z_{t-1}) + (1-\beta)h(c_{t-1})$,with $0 < \beta < 1$. In contrast to the previous case, habits now have an infinite memory. We can rewrite the specification for habits as $(1-\beta L)h(z_t) = (1-\beta)h(c_t)$, where L is the lag operator. We can then rewrite the expression for z_t as:

$$h(z_t) = \frac{1-\beta}{1-\beta L}h(c_{t-1}) \qquad (A.4)$$

In a more cumbersome notation this can also be written as:

$$h(z_t) = \sum_{\tau=-\infty}^{t-1}\beta^{t-\tau}h(c_\tau) = \beta^t h(z_0) + (1-\beta)\sum_{\tau=1}^{t-1}\beta^{t-\tau}h(c_\tau) \qquad (A.5)$$

where

$$h(z_0) = \sum_{\tau=-\infty}^{0}\beta^{-\tau}h(c_{\tau-1}) \qquad (A.6)$$

The only difference with the AR-case lies in the definition of the habit variable z_τ^i. We now define:

$$\ln z_t^i = \beta^{t-l}\ln z_0 + (1-\beta)\sum_{\tau=l}^{t-1}\beta^{t-1-\tau}\ln c_\tau^i, \qquad t > l \qquad (A.7)$$

For age l we define $\ln z_l \equiv \ln z_0^i$. Furthermore, $\ln c_\tau^i = (\tau - l)\ln A_i + \ln c_l^i$, for $\tau \geqslant l$. We can use this to rewrite (A.7):

$$\begin{aligned}\ln z_t^i &= \beta^{t-l}\ln z_0^i + (1-\beta)[\sum_{\tau=l}^{t-1}\beta^{t-1-\tau}(\tau-l)\ln A_i + \sum_{\tau=l}^{t-1}\beta^{t-1-\tau}\ln c_l^i], \qquad t > l \qquad (A.8) \\ &= \ln z_0, \qquad t = l\end{aligned}$$

Now consider

$$\begin{aligned}
\ln c_t^i - \theta \ln z_t^i &= (t-l)\ln A_i + \ln c_l^i - \theta(\beta^{t-l}\ln z_0^i + \\
&\quad (1-\beta)[\ln A_i \sum_{\tau=l}^{t-1}\beta^{t-1-\tau}(\tau-l) + \ln c_l^i \sum_{\tau=l}^{t-1}\beta^{t-1-\tau}]) \\
&= (t-l)\ln A_i + \ln c_l^i - \theta(\beta^{t-l}\ln z_0^i + \\
&\quad (1-\beta)[\ln A_i \frac{\beta^{t-l} - 1 + (1-\beta)(t-l)}{(1-\beta)^2} \\
&\quad + \ln c_l^i \frac{1-\beta^{t-l}}{1-\beta}]) \\
&= (t-l)(1-\theta)\ln A_i + (1-\theta)\ln c_l^i + \theta\frac{\ln A_i}{1-\beta} \\
&\quad -\theta\beta^{t-l}[\ln z_0^i + \frac{\ln A_i}{1-\beta} - \ln c_l^i], \qquad t > l \\
&= \ln c_l^i - \theta \ln z_0^i \qquad t = l
\end{aligned} \tag{A.9}$$

Next we consider the utility function:

$$\begin{aligned}
\overline{u} &= \sum_{\tau=l}^{L}(1+\delta)^{l-\tau}\frac{1}{1-\rho}(\frac{c_\tau^i}{(z_\tau^i)^\theta})^{1-\rho} \\
&= \sum_{\tau=l}^{L}(1+\delta)^{l-\tau}\frac{1}{1-\rho}\exp[(1-\rho)(\ln c_\tau^i - \theta\ln z_\tau^i)] \equiv \frac{1}{1-\rho}\sum_{\tau=l}^{L}\exp[\Omega_{\tau-l}]
\end{aligned} \tag{A.10}$$

with $\Omega_{\tau-l}$ defined as follows:

$$\Omega_{\tau-l} \equiv (l-\tau)\ln(1+\delta) + (1-\rho)(\ln c_\tau^i - \theta\ln z_\tau^i) \tag{A.11}$$

Upon using (A.9) this can be written as

$$\begin{aligned}
\Omega_{\tau-l} &= (\tau-l)[(1-\rho)(1-\theta)\ln A_i - \ln(1+\delta)] \\
&\quad -\beta^{\tau-l}(1-\rho)\theta[\ln z_0 + \frac{\ln A_i}{1-\beta} - \ln c_l^i] \\
&\quad +(1-\rho)[(1-\theta)\ln c_l^i + \theta\frac{\ln A_i}{1-\beta}], \qquad \tau > l
\end{aligned} \tag{A.12}$$

$$= (1-\rho)[\ln c_l^i - \theta\ln z_0^i], \qquad \tau = l \tag{A.13}$$

Let us define

$$\Pi_i \equiv (1-\rho)(1-\theta)\ln A_i - \ln(1+\delta) \tag{A.14}$$

$$\Lambda_i \equiv (1-\rho)\theta[\ln z_0^i + \frac{\ln A_i}{1-\beta} - \ln c_l^i] \tag{A.15}$$

$$\Xi_i \equiv (1-\rho)[(1-\theta)\ln c_l^i + \theta\frac{\ln A_i}{1-\beta}] \tag{A.16}$$

Then we can write (A.10) as

$$\begin{aligned} \overline{u} &= \frac{1}{1-\rho}\left(\frac{c_l^i}{z_0^\theta}\right)^{1-\rho} + \frac{1}{1-\rho}\sum_{\tau=l+1}^{L}\exp[\Pi_i(\tau-l) - \Lambda_i\beta^{\tau-l} + \Xi_i] \qquad \text{(A.17)} \\ &= \frac{1}{1-\rho}\left(\frac{c_l^i}{z_0^\theta}\right)^{1-\rho} + \frac{\exp(\Xi_i)}{1-\rho}\sum_{\tau=l+1}^{L}\exp[\Pi_i(\tau-l) - \Lambda_i\beta^{\tau-l}] \end{aligned}$$

Appendix B

The IES for the model with habit formation.

Below we derive the IES for the model with moving average habit formation. This also covers the AR-case, as the AR-case is a special case of MA, obtained by setting $\beta = 0$. Our derivation closely follows Carroll (2000), which provides a derivation of the Euler equation with a slightly different specification of habit formation. For the purpose of the derivation we simplify the notation somewhat by omitting the superscript i. For a start, recall the specification of the utility function and the specification of the habit formation equation:

$$u(c, z) = \frac{1}{1-\rho}(\frac{c}{z^{\theta}})^{1-\rho} \tag{B.1}$$

$$\ln z_t = \beta \ln z_{t-1} + (1-\beta)\ln c_{t-1} = \ln z_{t-1} + (1-\beta)[\ln c_{t-1} - \ln z_{t-1}] \tag{B.2}$$

Some useful derivatives of the utility function are:

$$u^c = (\frac{c}{z^{\theta}})^{-\rho} z^{-\theta} \tag{B.3}$$

$$u^z = -\theta(\frac{c}{z^{\theta}})^{-\rho}\frac{c}{z^{\theta+1}} \tag{B.4}$$

The Bellman equation for the problem of maximizing the additive intertemporal utility function is:

$$v_t(x_t, z_t) = \max_{c_t} u(c_t, z_t) + \frac{1}{1+\delta} v_{t+1}(x_{t+1}, z_{t+1}) \tag{B.5}$$

subject to

$$x_{t+1} = R(x_t - c_t) + y_t \tag{B.6}$$

$$\ln z_{t+1} = \ln z_t + (1-\beta)[\ln c_t - \ln z_t] \tag{B.7}$$

where R is one plus the interest rate, x_t is cash on hand, y_t is income in period t. The first order condition for a maximum is:

$$u_t^c + \frac{1}{1+\delta}[(1-\beta)v_{t+1}^z \frac{z_{t+1}}{c_t} - Rv_{t+1}^x)] = 0 \qquad \Longrightarrow \tag{B.8}$$

$$u_t^c = \frac{1}{1+\delta}[Rv_{t+1}^x - (1-\beta)v_{t+1}^z \frac{z_{t+1}}{c_t})] \tag{B.9}$$

Next, exploit the envelope theorem to obtain

$$v_t^x = \frac{\partial v_t}{\partial x_t} + \overbrace{\frac{\partial v_t}{\partial c_t}}^{=0} \frac{\partial c_t}{\partial x_t} = \frac{\partial v_t}{\partial x_t} = \frac{R}{1+\delta} v_{t+1}^x \tag{B.10}$$

Combining this with (B.9) yields

$$v_t^x = u_t^c + \frac{1-\beta}{1+\delta} \frac{z_{t+1}}{c_t} v_{t+1}^z \tag{B.11}$$

Similarly,

$$v_t^z = \frac{\partial v_t}{\partial z_t} + \overbrace{\frac{\partial v_t}{\partial c_t}}^{=0} \frac{\partial c_t}{\partial z_t} = \frac{\partial v_t}{\partial x_t} = u_t^z + \frac{1}{1+\delta} v_{t+1}^z \frac{\partial z_{t+1}}{\partial z_t} = u_t^z + \frac{\beta}{1+\delta} v_{t+1}^z \frac{z_{t+1}}{z_t} \tag{B.12}$$

This implies

$$v_{t+1}^z = u_{t+1}^z + \frac{\beta}{1+\delta} v_{t+2}^z \frac{z_{t+2}}{z_{t+1}} \tag{B.13}$$

Substituting the expression for v_{t+1}^z in (B.11) yields

$$u_t^c = v_t^x - \frac{1-\beta}{1+\delta} \frac{z_{t+1}}{c_t} u_{t+1}^z - \frac{\beta(1-\beta)}{(1+\delta)^2} \frac{z_{t+2}}{c_t} v_{t+2}^z \tag{B.14}$$

(B.11) implies

$$v_{t+1}^x = u_{t+1}^c + \frac{1-\beta}{1+\delta} \frac{z_{t+2}}{c_{t+1}} v_{t+2}^z \qquad \Longrightarrow \tag{B.15}$$

$$\frac{1-\beta}{1+\delta} z_{t+2} v_{t+2}^z = c_{t+1} v_{t+1}^x - c_{t+1} u_{t+1}^c \tag{B.16}$$

Substituting this in (B.14) yields

$$\begin{aligned} u_t^c &= v_t^x - \frac{1-\beta}{1+\delta}\frac{z_{t+1}}{c_t}u_{t+1}^z - \frac{\beta}{1+\delta}\frac{c_{t+1}}{c_t}[v_{t+1}^x - u_{t+1}^c] \\ &= v_t^x - \frac{\beta}{1+\delta}\frac{c_{t+1}}{c_t}v_{t+1}^x - \frac{1}{1+\delta}[(1-\beta)\frac{z_{t+1}}{c_t}u_{t+1}^z - \beta\frac{c_{t+1}}{c_t}u_{t+1}^c] \\ &= v_t^x - \frac{\beta}{R}\frac{c_{t+1}}{c_t}v_t^x - \frac{1}{1+\delta}[(1-\beta)\frac{z_{t+1}}{c_t}u_{t+1}^z - \beta\frac{c_{t+1}}{c_t}u_{t+1}^c] \\ &= [1-\frac{\beta}{R}\frac{c_{t+1}}{c_t}]v_t^x - \frac{1}{1+\delta}[(1-\beta)\frac{z_{t+1}}{c_t}u_{t+1}^z - \beta\frac{c_{t+1}}{c_t}u_{t+1}^c] \qquad \text{(B.17)} \end{aligned}$$

(B.17) implies

$$u_{t+1}^c = [1-\frac{\beta}{R}\frac{c_{t+2}}{c_{t+1}}]v_{t+1}^x - \frac{1}{1+\delta}[(1-\beta)\frac{z_{t+2}}{c_{t+1}}u_{t+2}^z - \beta\frac{c_{t+2}}{c_{t+1}}u_{t+2}^c] \qquad \text{(B.18)}$$

So that

$$v_{t+1}^x = [1-\frac{\beta}{R}\frac{c_{t+2}}{c_{t+1}}]^{-1}\left\{\frac{1}{1+\delta}[(1-\beta)\frac{z_{t+2}}{c_{t+1}}u_{t+2}^z - \beta\frac{c_{t+2}}{c_{t+1}}u_{t+2}^c] + u_{t+1}^c\right\} \qquad \text{(B.19)}$$

Define

$$B_t \equiv \frac{1-\frac{\beta}{R}\frac{c_{t+1}}{c_t}}{1-\frac{\beta}{R}\frac{c_{t+2}}{c_{t+1}}} \qquad \text{(B.20)}$$

Combining (B.19) with (B.17) and (B.10) yields

$$\begin{aligned} u_t^c &= [1-\frac{\beta}{R}\frac{c_{t+1}}{c_t}]\frac{R}{1+\delta}v_{t+1}^x - \frac{1}{1+\delta}[(1-\beta)\frac{z_{t+1}}{c_t}u_{t+1}^z - \beta\frac{c_{t+1}}{c_t}u_{t+1}^c] \\ &= B_t\frac{R}{1+\delta}\left\{\frac{1}{1+\delta}[(1-\beta)\frac{z_{t+2}}{c_{t+1}}u_{t+2}^z - \beta\frac{c_{t+2}}{c_{t+1}}u_{t+2}^c] + u_{t+1}^c\right\} \\ &\quad -\frac{1}{1+\delta}[(1-\beta)\frac{z_{t+1}}{c_t}u_{t+1}^z - \beta\frac{c_{t+1}}{c_t}u_{t+1}^c] \qquad \text{(B.21)} \end{aligned}$$

which is the Euler equation for consumption.

Using (B.3) and (B.4) this can be written as

$$\begin{aligned} \frac{c_{t+1}}{c_t}\left(\frac{c_t}{z_t^\theta}\right)^{1-\rho} &= -B_t\frac{R}{1+\delta}\left\{\frac{1}{1+\delta}\left(\frac{c_{t+2}}{z_{t+2}^\theta}\right)^{1-\rho}[\theta(1-\beta)+\beta] - \left(\frac{c_t+1}{z_{t+1}^\theta}\right)^{1-\rho}\right\} \\ &\quad +\frac{1}{1+\delta}\frac{c_{t+1}}{c_t}\left(\frac{c_t+1}{z_{t+1}^\theta}\right)^{1-\rho}\{\theta(1-\beta)+\beta\} \qquad \text{(B.22)} \end{aligned}$$

In principle equation (B.22) can be used to derive the IES for any given consumption history. Such a derivation leads to rather messy formulas. It is therefore probably of more interest to find the IES for a steady state consumption path.

Let us assume therefore that consumption grows at a constant rate σ, i.e.

$$\ln c_{t+1} - \ln c_t = \ln \sigma \tag{B.23}$$

and similarly for the stock of habits. Equation (B.2) then implies that

$$\ln \sigma = (1-\beta)(\ln c_t - \ln z_t) \qquad \Longrightarrow \tag{B.24}$$

so that

$$\frac{c_t}{z_t} = \sigma^{\frac{1}{1-\beta}} \qquad and \qquad \frac{c_t}{z_t^{\theta}} = c_t^{1-\theta}\sigma^{\frac{\theta}{1-\beta}} \tag{B.25}$$

The last expression has a straightforward interpretation. For example, if $\theta = 1$, utility only depends on the growth rate of consumption, but not on consumption itself. If θ approaches 0 utility only depends on the level of consumption. If θ is not equal to 0 the parameter β determines how strongly consumption growth affects utility. If β tends to 1 (i.e., when the habit formation process has a long memory and last period's consumption has a small effect on the stock of habits), utility at a given rate of growth is higher than in the case where β tends to 0. The reason for this is simply that at a given rate of growth the ratio between current consumption and the stock of habits is bigger with a long memory than with a short memory.

The assumption of a steady state consumption growth simplifies (B.22) considerably. The variable B_t reduces to 1. Furthermore, define the parameter $\chi \equiv \sigma^{\frac{1}{1-\beta}}$, so that

$$\frac{c_t}{z_t^{\theta}} = c_t^{1-\theta}\chi^{\theta} \tag{B.26}$$

Then we can write (B.22) as

$$\begin{aligned}\sigma[c_t^{1-\theta}\chi^{\theta}]^{1-\rho} \quad &= \quad -\frac{R}{1+\delta}\left\{\frac{1}{1+\delta}\left(\sigma^{2(1-\theta)}c_t^{1-\theta}\chi^{\theta}\right)^{1-\rho}[\theta(1-\beta)+\beta] - \left(\sigma^{1-\theta}c_t^{1-\theta}\chi^{\theta}\right)^{1-\rho}\right\} \\ &\quad +\frac{1}{1+\delta}\sigma\left(\sigma^{1-\theta}c_t^{1-\theta}\chi^{\theta}\right)^{1-\rho}[\theta(1-\beta)+\beta] \end{aligned} \tag{B.27}$$

Or

$$\sigma = -\frac{R}{1+\delta}\left\{\frac{1}{1+\delta}\sigma^{2(1-\theta)(1-\rho)}[\theta(1-\beta)+\beta] - \sigma^{(1-\theta)(1-\rho)}\right\} + \frac{\sigma}{1+\delta}\sigma^{(1-\theta)(1-\rho)}[\theta(1-\beta)+\beta] \tag{B.28}$$

Define $\varepsilon \equiv \theta(1-\beta)+\beta$ and

$$\eta \equiv \frac{\sigma^{(1-\theta)(1-\rho)}}{1+\delta} \tag{B.29}$$

Then (B.28) can be written as:

$$\sigma = -R\left\{\varepsilon\eta^2 - \eta\right\} + \sigma\varepsilon\eta \qquad \Longrightarrow \tag{B.30}$$

$$R\varepsilon\eta^2 - [R+\sigma\varepsilon]\eta + \sigma = 0 \tag{B.31}$$

(B.31) is a quadratic equation in η. Solving for η yields the following two solutions:

$$\eta_1 = \frac{1}{\varepsilon} \tag{B.32}$$

$$\eta_2 = \frac{\sigma}{R} \tag{B.33}$$

To check which solution corresponds to a utility maximum, we consider the special case $\theta = 0$. It turns out that for (B.33) we retrieve the usual Euler equation for the case without habit formation. (B.29) and (B.33) imply

$$\frac{\sigma^{(1-\theta)(1-\rho)}}{1+\delta} = \frac{\sigma}{R} \qquad \Longrightarrow \tag{B.34}$$

$$\begin{aligned} \ln\sigma &= \frac{1}{\rho+\theta-\rho\theta}[\ln R - \ln(1+\delta)] \\ &\approx \frac{1}{\rho+\theta-\rho\theta}(r-\delta) \end{aligned} \tag{B.35}$$

where $r = R - 1$, i.e. the interest rate.

Appendix C

The likelihood for k=3

For $k = 3$ there are four possible ownership patterns for the two risky assets: (1) $w_1 = 0$, $w_2 = 0$; (2) $w_1 \neq 0$, $w_2 = 0$; (3) $w_1 = 0$, $w_2 \neq 0$; (4) $w_1 \neq 0$, $w_2 \neq 0$. We will discuss these consecutively. For later use we introduce some scalar notation:

$$\begin{aligned} \Gamma &\equiv \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix}, \quad \Omega \equiv \begin{bmatrix} \omega_1^2 & \rho\omega_1\omega_2 \\ \rho\omega_1\omega_2 & \omega_2^2 \end{bmatrix} \quad w_i \equiv \begin{pmatrix} w_{i1} \\ w_{i2} \end{pmatrix} \\ \overline{z}_i &\equiv \begin{pmatrix} \overline{z}_{i1} \\ \overline{z}_{i2} \end{pmatrix}, \quad \mu_i^* \equiv \begin{pmatrix} \mu_{i1}^* \\ \mu_{i2}^* \end{pmatrix} \end{aligned} \tag{C.1}$$

For the various normal distributions and densities the following notation is adopted. $B\Phi\left[\begin{pmatrix} x_1 \\ x_2 \end{pmatrix}; \upsilon, \Sigma\right]$ represents the joint probability that two normally distributed random variables, with mean vector υ and variance-covariance matrix Σ, are less than or equal to x_1 and x_2, respectively. $B\phi\left[\begin{pmatrix} x_1 \\ x_2 \end{pmatrix}; \upsilon, \Sigma\right]$ is the value of the corresponding density at the point $\begin{pmatrix} x_1 \\ x_2 \end{pmatrix}$. $\Phi[x; \mu, \sigma]$ is the probability that a normally distributed variable, with mean μ and variance σ^2, is less than or equal to x. $\phi[x; \mu, \sigma]$ is the value of the corresponding density at the point x.

C.1 $w_1 = 0$, $w_2 = 0$

For this case the likelihood contribution is the bivariate probability that both Lagrange multipliers are non-negative, or in other words that $\Gamma^{-1}\widetilde{w}_i \leq 0$. Thus the likelihood contribution for this case is:

$$\mathcal{L}_{1i} = B\Phi\left[(0)\,;\left(\Gamma^{-1}[\overline{z}_i + \Gamma\mu_i^*]\right), \Gamma^{-1}\Omega(\Gamma^{-1})'\right] \tag{C.2}$$

The matrix Γ is assumed symmetric, so the transposition sign is superfluous, strictly speaking. Define $D \equiv |\Gamma| = \gamma_{11}\gamma_{22} - \gamma_{12}\gamma_{21}$. Then we can write

$$\Gamma^{-1}[\overline{z}_i + \Gamma\mu_i^*] = \frac{1}{D}\left[\begin{array}{c} \gamma_{22}\overline{z}_1 - \gamma_{12}\overline{z}_1 + \mu_1^* \\ \gamma_{11}\overline{z}_2 - \gamma_{21}\overline{z}_1 + \mu_2^* \end{array}\right] \tag{C.3}$$

$$\Gamma^{-1}\Omega(\Gamma^{-1})' \equiv \frac{1}{D^2}\left(\begin{array}{cc} \Theta_{11} & \Theta_{12} \\ \Theta_{12} & \Theta_{22} \end{array}\right) \tag{C.4}$$

with

$$\begin{aligned} \Theta_{11} &= (\gamma_{22})^2\omega_1^2 - 2\gamma_{12}\gamma_{22}\rho\omega_1\omega_2 + (\gamma_{12})^2\omega_2^2 \\ \Theta_{12} &= -\gamma_{22}\gamma_{21}\omega_1^2 + (\gamma_{11}\gamma_{22} + \gamma_{12}\gamma_{21})\rho\omega_1\omega_2 - \gamma_{11}\gamma_{12}\omega_2^2 \\ \Theta_{22} &= (\gamma_{11})^2\omega_2^2 - 2\gamma_{11}\gamma_{21}\rho\omega_1\omega_2 + (\gamma_{21})^2\omega_1^2 \end{aligned} \tag{C.5}$$

C.2 $w_1 \neq 0$, $w_2 = 0$

For this case we have $S_i' = \left(\begin{array}{cc} 0 & 1 \end{array}\right)$, $D_i' = \left(\begin{array}{cc} 1 & 0 \end{array}\right)$, $S_i'\Gamma S_i = \gamma_{22}$. Thus, $(S_i'\Gamma S_i)^{-1}w_i = \frac{w_{i2}}{\gamma_{22}}$. Hence, $(S_i'\Gamma S_i)^{-1}w_i \leq 0$ is equivalent with $w_{i2} \leq 0$. Furthermore we have $\Delta_i' = D_i'[I - \Gamma S_i(S_i'\Gamma S_i)^{-1}S_i'] = \left(\begin{array}{cc} 1 & -\frac{\gamma_{12}}{\gamma_{22}} \end{array}\right)$, $S_i'\Omega\Delta_i = -\frac{\gamma_{12}}{\gamma_{22}}...\omega_2^2 + \rho\omega_1\omega_2$, and $\Delta_i'\Omega\Delta_i = \omega_1^2 - 2\rho\frac{\gamma_{12}}{\gamma_{22}}\omega_1\omega_2 + \left(\frac{\gamma_{12}}{\gamma_{22}}\right)^2\omega_2^2$. Hence, the marginal density of w_{i1} is normal with variance

$$\sigma_1^2 \equiv \Delta_i'\Omega\Delta_i = \omega_1^2 - 2\rho\frac{\gamma_{12}}{\gamma_{22}}\omega_1\omega_2 + \left(\frac{\gamma_{12}}{\gamma_{22}}\right)^2\omega_2^2 \tag{C.6}$$

and mean

$$\chi_{i1} \equiv \Delta_i'\overline{z}_i + \Delta_i'\Gamma\mu_i^* = -\frac{\gamma_{12}}{\gamma_{22}}\overline{z}_{i2} + \overline{z}_{i1} + (\gamma_{11} - \frac{\gamma_{21}\gamma_{12}}{\gamma_{22}})\mu_{i1}^* \tag{C.7}$$

The conditional variance of the latent budget share $\widetilde{w}_{i2}$ given w_{i1} (cf. (3.31), but without pre- and postmultiplication by $(S_i'\Gamma S_i)^{-1}$) becomes

$$\eta_2^2 \equiv S_i'\Omega S_i - S_i'\Omega\Delta_i(\Delta_i'\Omega\Delta_i)^{-1}\Delta_i'\Omega S_i = \omega_2^2 - \frac{\left(-\frac{\gamma_{12}}{\gamma_{22}}...\omega_2^2 + \rho\omega_1\omega_2\right)^2}{\omega_1^2 - 2\rho\frac{\gamma_{12}}{\gamma_{22}}\omega_1\omega_2 + \left(\frac{\gamma_{12}}{\gamma_{22}}\right)^2\omega_2^2} \tag{C.8}$$

Similarly we have $S_i'\Omega\Delta_i(\Delta_i'\Omega\Delta_i)^{-1} = \frac{-\frac{\gamma_{12}}{\gamma_{22}}.\omega_2^2+\rho\omega_1\omega_2}{\omega_1^2-2\rho\frac{\gamma_{12}}{\gamma_{22}}\omega_1\omega_2+\left(\frac{\gamma_{12}}{\gamma_{22}}\right)^2\omega_2^2}$. Thus it follows from (3.32) (omitting premultiplication by $(S_i'\Gamma S_i)^{-1}$) that the conditional mean of w_{i2} given w_{i1} is given by

$$\begin{aligned}\nu_{i2} &\equiv S_i'\overline{z}_i + S_i'\Gamma\mu_i^* + S_i'\Omega\Delta_i(\Delta_i'\Omega\Delta_i)^{-1}[D_i'w_i - \Delta_i'\overline{z}_i - \Psi_i S_i'\mu_i^*] \\ &= \overline{z}_{i2} + \gamma_{21}\mu_{i1}^* + \gamma_{22}\mu_{i2}^* + \\ &\quad \frac{-\frac{\gamma_{12}}{\gamma_{22}}.\omega_2^2 + \rho\omega_1\omega_2}{\omega_1^2 - 2\rho\frac{\gamma_{12}}{\gamma_{22}}\omega_1\omega_2 + \left(\frac{\gamma_{12}}{\gamma_{22}}\right)^2\omega_2^2}\{w_{i1} - \chi_{i1}\} \end{aligned} \tag{C.9}$$

For the likelihood contribution of this case we obtain:

$$\mathcal{L}_{2i} \equiv \Phi[0; \nu_{i2}, \eta_2].\varphi[w_{i1}; \chi_{i1}, \sigma_1] \tag{C.10}$$

C.3 $w_1 = 0$, $w_2 \neq 0$

For this case we have $S_i' = \begin{pmatrix} 1 & 0 \end{pmatrix}$, $D_i' = \begin{pmatrix} 0 & 1 \end{pmatrix}$. Similar to previous case, the condition that the Lagrange multiplier for the binding constraint is non-negative is equivalent with $w_{i1} \leq 0$. Furthermore, $\Delta_i' = D_i'[I - \Gamma S_i(S_i'\Gamma S_i)^{-1}S_i'] = \begin{pmatrix} -\frac{\gamma_{21}}{\gamma_{11}} & 1 \end{pmatrix}$, $S_i'\Omega\Delta_i = -\frac{\gamma_{21}}{\gamma_{11}}...\omega_1^2 + \rho\omega_1\omega_2$, $\Delta_i'\Omega\Delta_i = \omega_2^2 - 2\rho\frac{\gamma_{21}}{\gamma_{11}}\omega_1\omega_2 + \left(\frac{\gamma_{21}}{\gamma_{11}}\right)^2\omega_1^2$. Hence the marginal density of w_{i2} is normal with variance

$$\sigma_2^2 \equiv \Delta_i'\Omega\Delta_i = \omega_2^2 - 2\rho\frac{\gamma_{21}}{\gamma_{11}}\omega_1\omega_2 + \left(\frac{\gamma_{21}}{\gamma_{11}}\right)^2\omega_1^2 \tag{C.11}$$

and mean

$$\chi_{i2} \equiv \Delta_i'\overline{z}_i + \Delta_i'\Gamma\mu_i^* = -\frac{\gamma_{21}}{\gamma_{11}}\overline{z}_{i1} + \overline{z}_{i2} + (\gamma_{22} - \frac{\gamma_{21}\gamma_{12}}{\gamma_{11}})\mu_{i1}^* \tag{C.12}$$

.The conditional variance of latent budget share w_{i1} given w_{i2} as given in (3.31) (but without pre- and postmultiplication by $(S_i'\Gamma S_i)^{-1}$) becomes

$$\eta_1^2 \equiv S_i'\Omega S_i - S_i'\Omega\Delta_i(\Delta_i'\Omega\Delta_i)^{-1}\Delta_i'\Omega S_i = \omega_1^2 - \frac{\left(-\frac{\gamma_{21}}{\gamma_{11}}...\omega_1^2 + \rho\omega_1\omega_2\right)^2}{\omega_2^2 - 2\rho\frac{\gamma_{21}}{\gamma_{11}}\omega_1\omega_2 + \left(\frac{\gamma_{21}}{\gamma_{11}}\right)^2\omega_1^2} \tag{C.13}$$

Similarly we have $S_i'\Omega\Delta_i(\Delta_i'\Omega\Delta_i)^{-1} = \frac{-\frac{\gamma_{21}}{\gamma_{11}}.\omega_1^2+\rho\omega_1\omega_2}{\omega_2^2-2\rho\frac{\gamma_{21}}{\gamma_{11}}\omega_1\omega_2+\left(\frac{\gamma_{21}}{\gamma_{11}}\right)^2\omega_1^2}$. Thus it follows from (3.32) (omitting premultiplication by $(S_i'\Gamma S_i)^{-1}$) that the conditional mean of w_{i1} given w_{i2} is given by

$$\begin{aligned}\nu_{i1} &\equiv S_i'\overline{z}_i + S_i'\Gamma\mu_i^* + S_i'\Omega\Delta_i(\Delta_i'\Omega\Delta_i)^{-1}[D_i'w_i - \chi_{i2}] \\ &= \overline{z}_{i1} + \gamma_{11}\mu_{i1}^* + \gamma_{12}\mu_{i2}^* + \\ &\quad \frac{-\frac{\gamma_{21}}{\gamma_{11}}.\omega_1^2 + \rho\omega_1\omega_2}{\omega_2^2 - 2\rho\frac{\gamma_{21}}{\gamma_{11}}\omega_1\omega_2 + \left(\frac{\gamma_{21}}{\gamma_{11}}\right)^2\omega_1^2}\{w_{i2} - \chi_{i2}\}\end{aligned} \tag{C.14}$$

For the likelihood contribution of this case we obtain:

$$\mathcal{L}_{3i} \equiv \Phi[0; \nu_{i1}, \eta_1].\varphi[w_{i2}; \chi_{i2}, \sigma_2] \tag{C.15}$$

C.4 $w_1 \neq 0$, $w_2 \neq 0$

This case is straightforward. The likelihood contribution is simply the bivariate density of w_1 and w_2 as generated by (3.25). Thus the likelihood contribution for this case is:

$$\mathcal{L}_{4i} = B\phi\left[\begin{pmatrix} w_1 \\ w_2 \end{pmatrix}; \begin{pmatrix} \overline{z}_{i1} + \gamma_{11}\mu_{i1}^* + \gamma_{12}\mu_{i2}^* \\ \overline{z}_{i2} + \gamma_{21}\mu_{i1}^* + \gamma_{22}\mu_{i2}^* \end{pmatrix}, \Omega\right] \tag{C.16}$$

Appendix

Samenvatting

Dit proefschrift behandelt individuele financiële besluitvorming. Besluitvorming betreft het proces waarin een geprefereerde optie uit een set van alternatieven wordt gekozen. Het begint vaak met het verzamelen van informatie en wordt gevolgd door een afwegingsproces, tot uiteindelijk gekozen wordt. Het bestuderen van besluitvorming is interdisciplinair van aard en omvat economie, politieke wetenschap, sociologie, psychologie, statistiek en filosofie.

Individueel gedrag wordt van oudsher in de economische wetenschap bestudeerd met behulp van het **rationele-keuzemodel**, waarin aangenomen wordt dat individuen een bepaalde doelstellingsfunctie maximaliseren onder de voorwaarden waarmee zij in hun streven naar het vergroten van hun eigenbelang worden geconfronteerd. Dit onderwerp is tot ontwikkeling gekomen in de keuzetheorie (Luce en Raiffa, 1957), keuze-analyse (Raiffa, 1968), speltheorie (Von Neumann en Morgenstern, 1953), politieke theorie (Mueller, 1989), psychologie (Kahneman, Slovic en Tversky, 1982) en economie (Debreu, 1959; Henderson en Quandt, 1980). In economische analyses wordt het nutsbegrip typisch benaderd door een wiskundige weergave van de preferenties die een individu heeft over alternatieve pakketten consumptiegoederen, of, meer in het algemeen, over goederen, diensten en vrije tijd. Het concept van rationeel gedrag heeft als voordeel dat het de analyse van individueel gedrag eenvoudiger maakt dan een minder gestructureerde aanname zou toelaten, en kan op twee manieren worden geïnterpreteerd. Ten eerste kan zo optimaal economisch gedrag op een normatieve manier worden afgeleid. Ten tweede kunnen modellen van rationeel gedrag worden gebruikt om feitelijk en waargenomen gedrag te verklaren. De theorie van subjectief verwacht nut (Savage, 1954) is het centrale element van de neoklassieke theorie van rationeel economisch gedrag en is daarmee het belangrijkste voorbeeld van een theorie over rationeel gedrag. De basisaannames zijn dat keuzes worden gemaakt uit een gegeven, vaste set van alternatieven, met (subjectief) bekende kansverdelingen van de uitkomsten van elk alternatief en zodanig dat de verwachte waarde van een gegeven nutsfunctie wordt gemaximaliseerd.

Hoewel deze aannames voor veel doeleinden geschikt zijn, zouden ze empirisch niet kunnen aansluiten bij veel economische keuzesituaties. Een toenemend aantal economen wordt zich bewust van het feit dat ze, om hun modellen relevanter en realistischer te maken, rekening moeten houden met (overgenomen) inzichten en methodologieën uit verschillende wetenschapsgebieden, te weten psychologie en andere sociale wetenschappen. Dit is het onderwerp van de theorie van **begrensde rationaliteit** en het onderzoeksgebied van "behavioral economics". De term "begrensde rationaliteit" (Simon, 1995) wordt gebruikt ter aanduiding van modellen die de cognitieve beperkingen van zowel kennis als cognitieve capaciteit in aanmerking nemen. Begrensde rationaliteit is een centraal thema in "behavioral economics". Het wijkt af van één of meer van de neoklassieke aannames die aan de theorie van rationeel gedrag ten grondslag liggen, dat wil zeggen, theorieën over begrensde rationaliteit zwakken één of meerdere aannames van de standaard verwachte nutstheorie af. "Behavioral economics" is de toepassing van psychologische theorie en onderzoek op economie. Het onderzoekt wat gebeurt in markten waarin sommige individuen menselijke beperkingen en complicaties vertonen. Onderzoek in "behavioral economics" heeft specifieke methodologische benaderingen overgenomen die de traditionele statistische en econometrische toetsen van economische modellen aanvullen. In "behavioral economics" is het bijvoorbeeld gangbaar om gebruik te maken van experimenten, en enquêtegegevens worden ook steeds belangrijker bij het vergroten van inzicht in het feitelijke besluitvormingsproces van individuen.

Zoals reeds vermeld, richt dit proefschrift zich op de empirische bestudering van financiële besluitvorming op individueel niveau. De analyse van begrippen als risicohouding, intertemporele keuze, tijdsvoorkeur en gewoontevorming wordt volgens een positieve benaderingswijze uitgevoerd, gebaseerd op empirische waarneming en op experimentele studies van keuzegedrag. De schatting van (sommige) parameters betreffende de preferenties verschaft extra bevindingen aan een uitgebreide literatuur waar nog steeds ruimte is voor discussie over de vraag hoe individuen in werkelijkheid keuzes maken. Het proefschrift bestaat uit vier hoofdstukken die onafhankelijk van elkaar kunnen worden gelezen. Het startpunt van alle hoofdstukken is het standaard rationele-keuzemodel. Individuen worden verondersteld een bepaalde preferentieordening te hebben ten aanzien van risicovolle vooruitzichten waarvoor een aantal axioma's geldt. Risicovolle alternatieven kunnen worden beoordeeld onder deze aannames door middel van de verwachte-nutsfunctie. De kromming van de nutsfunctie is een maatstaf voor risicoaversie. Zoals gewoonlijk in de literatuur over risicoaversie, geeft dit proefschrift bewijs van het bestaan van risicoaversie aan de hand van informatie verkregen uit een enquête waarbij mensen gevraagd werd hoe ze zouden kiezen uit verschillende risicovolle vooruitzichten. Risicohouding is gerelateerd aan individuele karaktereigenschappen, namelijk leeftijd, geslacht en opleidingsniveau. Daarnaast worden maatstaven van risicohouding geïncorporeerd in een portefeuille-allocatie model, dat, rekening houdend met incomplete portefeuilles, portefeuillebestanddelen verklaart.

Dit proefschrift is grotendeels gewijd aan het verschaffen van additioneel empirisch bewijs over het intertemporele verdisconteringsproces. Over het algemeen hebben zowel in de psychologie als economie de meeste empirische bevindingen geleid tot de conclusie dat waarde en tijd een negatieve correlatie vertonen, zodat de waarde van een bepaald goed wordt verdisconteerd als een functie van het tijdstip waarop het zal worden ontvangen. Er zijn veel aanwijzingen dat de conventionele intertemporele additieve nutsformulering met exponentiële verdiscontering een ontoereikende modellering van dynamische keuze is, zodat alternatieve formuleringen zijn ontwikkeld. Twee belangrijke stromingen zijn de zogenaamde veranderende-voorkeurmodellen en zelfbeheersingmodellen. Veranderende-voorkeurmodellen verklaren het feit dat preferenties over de tijd veranderen zodat een consument, na verloop van tijd, zijn consumptieplannen zou kunnen herzien. Zelfbeheersing is onderzocht met behulp van modellen waarin het individu wordt gezien als een organisatie, zodat het probleem van zelfbeheersing in feite neerkomt op het principaal-agent conflict tussen eigenaar en manager van een bedrijf. Het is daarom niet verbazingwekkend dat het grootste deel van het onderzoek op dit terrein gebaseerd is op een speltheoretische analyse. In de literatuur zijn twee verschillende empirische benaderingen ontwikkeld om individuele preferentieparameters te schatten: de "revealed preference"-benadering en wat we de experimentele benadering zullen noemen. De eerste methode bestaat uit het maken van een aantal aannames over de werkelijke voorkeuren van een individu, het feitelijke gedrag observeren en daaruit de preferentieparameters halen. De experimentele methode bestaat uit het voorleggen aan geënquêteerden van directe keuzemogelijkheden die reële of hypothetische betalingen inhouden. Het voordeel van experimenten is dat men niet de hele omgeving waarin individuen opereren (in het bijzonder beperkingen en onzekerheid) hoeft te modelleren, maar zelf scenario's volledig kan specificeren. Men kan zich natuurlijk afvragen hoe serieus geënquêteerden proberen een eerlijk antwoord te geven, vooral op vragen die geen gevolgen voor henzelf hebben (hypothetische betalingen).

Dit proefschrift richt zich ook op gewoontevorming, hetgeen inhoudt dat het huidige nutsniveau van consumenten onder andere afhangt van huidige consumptie ten opzichte van een zekere gewenning die het gevolg is van consumptie in het verleden. Dit is recentelijk gebruikt om voorspellingen van tijdseparabele modellen op verschillen terreinen, zoals spaargedrag onder onzekerheid, te verbeteren. Gewoontes zijn vooral bruikbaar gebleken op drie gebieden van de macro-economische theorie. Ten eerste hebben sommige auteurs diverse formuleringen van gewoontevorming bestudeerd die onze kennis over de "equity premium puzzle" kunnen vergroten. Abel (1990) en Constantinides (1990) hebben, naast anderen, aangetoond dat het betrekken van gewoontevorming bij het standaard ruilmodel van een economie de "equity premium puzzle" doet verdwijnen (Mehra en Prescott, 1985). Ten tweede is voorgesteld deze referenties te gebruiken voor het analyseren van het waargenomen verband tussen besparingen en groei. Empirische bevindingen suggereren dat zowel bij landen als bij huishoudens inkomensgroei een significant positief effect heeft op de spaarquote (Edwards, 1995; Carroll en Weil, 1994). Carroll, Overland en Weil (2000) passen het standaard AK-model aan om gewoontevorming te laten zien en tonen aan dat uit dit model een positieve reactie van de spaarquote op de groei van het inkomen resulteert. Ten derde kunnen gewoontes noodzakelijk zijn bij de verklaring van het zeer frequente overmatige "smoothing" van geaggregeerde consumptie. Fuhrer (2000) is in staat langzame en "hump-shaped" reacties van consumptie op monetaire en andere schokken in een theoretisch model aan te tonen door gewoontevorming in de consumptiefunctie in te bouwen. Indien het nut van consumptie niet alleen afhangt van het consumptieniveau maar ook van de verandering van consumptie tussen de huidige en de laatste periode, dan zal een inkomensschok leiden tot een vertraagde reactie van consumptie. De redenering hierachter heeft te maken met anticipatie van huishoudens op het (negatieve) effect van huidige consumptie op het toekomstige marginale nut van consumptie. Dit impliceert een geleidelijke reactie van consumptie op een inkomensschok, corresponderend met de "hump-shaped" reactie die in de data wordt gevonden.

In hoofdstuk 2 worden disconteringsvoeten, intertemporele substitutie-elasticiteiten en gewoonte-persistentieparameters geschat uit data die volgen uit een enquête van het CentER Savings Survey (CSS) waarbij mensen gevraagd werd te kiezen tussen hypothetische consumptiestromen. Het CSS, voorheen bekend als het VSB panel, is een panel survey dat startte in 1993 en elk jaar gehouden werd. Tot 1997 bestond het CSS uit twee enquêtes. De eerste enquête (REP) moest representatief zijn voor de Nederlandse bevolking, zelfs als de feitelijke REP enquêtes niet geheel representatief zijn vanwege non-respons; het bestaat uit ongeveer 2000 huishoudens in elke ronde, inclusief nieuwe enquêtes die paneluitval compenseren. De tweede enquête (HIP) vertegenwoordigde het hoogste deciel van de inkomensverdeling en bevatte aanvankelijk zo'n 900 huishoudens. De meeste respondenten van de tweede enquête stopten in 1998, zodat het CSS sinds dat jaar alleen het REP omvatte. De CentER Savings Survey bestaat uit vijf vragenlijsten: werk en pensioenen, huisvesting en hypotheken, inkomen en gezondheid, bezittingen en schulden, economische en psychologische aspecten. De vragenlijsten werden per modem naar de deelnemers gestuurd, zij vulden deze op hun computer in en de antwoorden werden op dezelfde manier teruggestuurd. Dit betekent dat de vragenlijsten werden beantwoord zonder tussenkomst van een enquêteur en dat de deelnemers de vragen konden beantwoorden op een voor hen gelegen moment. Gezien onze doelstelling richten we ons voornamelijk op de enquête betreffende bezittingen en schulden en economische en psychologische aspecten. De eerste verschaft gedetailleerde informatie over veertig activa en schuldcategorieën, zowel financieel als reëel. De enquête over economische en psychologische aspecten behelst een zeer omvangrijke set vragen over verschillende onderwerpen, zoals onder andere persoonlijke karakteristieken, huishoudinkomen, verwachtingen over toekomstig inkomen, de opvatting over sparen en spaargedrag, risicoperceptie en risico-aversie, verwachtingen over de toekomst en vergelijking met de huidige situatie, planning van financiële zaken.

Dit hoofdstuk behoort tot een groeiende literatuur over het gebruik van hypothetische vragen in enquêtes bedoeld om parameters te schatten die vaak moeilijk uit "revealed preference" data te halen zijn. De meest verwante paper binnen deze literatuur is Barsky, Juster, Kimball en Shapiro's paper (QJE, 1997), waarin dezelfde vraag aan de orde komt, die op enigszins andere wijze benaderd wordt, gebruik makend van Amerikaanse data uit de Health and Retirement Survey. De gevolgde procedure in het hoofdstuk bestaat uit het parameteriseren van het levensnut van elk verloop waarmee de geënquêteerde wordt geconfronteerd als een functie van het niveau en de groei van consumptie over de jaren (die beide aselect voor elk pad en voor elke deelnemer bepaald worden), alsook van de parameters die de subjectieve disconteringsvoet voorstellen, de risico-aversie coëfficiënt en, in een later deel van het hoofdstuk, de mate van gewoontepersistentie. Vervolgens worden aan de hand van een logit benadering de betreffende parameters geschat door aan te nemen dat de deelnemer het hypothetische pad kiest dat haar het hoogste levensnut zou opleveren. Modellen met gewoontevorming blijken superieur aan modellen met intertemporele additieve preferenties. De schatting van de intertemporele substitutie-elasticiteit blijkt behoorlijk robuust wat de verschillende aannames over gewoontevorming betreft. Echter, de coëfficiënt van relatieve risico-aversie verandert substantieel bij andere specificaties. Dit toont het belang aan van het verbreken van het verband tussen de intertemporele substitutie-elasticiteit en risico-aversie in intertemporele modellen. De belangrijkste bevinding van onze empirische analyse is de verwerping van intertemporele additiviteit.

Het is algemeen bekend dat mensen de neiging hebben risico te mijden. Hoe groter hun afkeer, hoe groter hun vraag naar verzekering. Bovendien bepaalt risico-aversie ook de vraag naar risicovolle beleggingsobjecten zoals aandelen. Tot nu toe is er echter weinig bewijs van de houding van individuen ten opzichte van risico. Hoofdstuk 3 onderzoekt dit met een model dat de portefeuillesamenstelling van huishoudens beschrijft. Een aantal verschillende maatstaven van risicohouding wordt aangewend, inclusief vragen over keuzes tussen onzekere consumptiestromen zoals voorgesteld door Barsky e.a. (1997) en enkele ad hoc maatstaven. We maken gebruik van meerdere vragen uit het CSS en CentERpanel. Het CentERpanel, gestart in 1991, is een op internet gebaseerd telepanel. Het CentER Saving Survey zoals hierboven beschreven is een onderdeel van het CentERpanel, aangezien de deelnemende huishoudens van het laatstgenoemde telepanel tevens deelnemers zijn van het CSS. In feite richten de enquêtes van het CentERpanel zich op een grotere variëteit van subjecten, zodat informatie uit het CSS kan worden gecombineerd met antwoorden die door dezelfde huishoudens zijn gegeven op andere vragen van het CentERpanel. Zoals in Barsky e.a. (1997) en Arrondel (2000) wordt eerst de individuele variatie in risico-aversie maatstaven geanalyseerd en verklaard uit achtergrondkenmerken (zowel "objectieve" kenmerken als andere subjectieve maatstaven van risicopreferentie). Vervolgens worden de gemeten risicohoudingen verwerkt in een portefeuille-allocatiemodel voor huishoudens, dat de portefeuillesamenstelling verklaart, rekening houdend met incomplete portefeuilles. We bouwen een structureel model met endogeen wisselende regimes, waarbij elk regime gekenmerkt wordt door een zeker patroon van aandelenbezit. Het model heeft twee componenten: de eerste bepaalt het regime en de tweede beschrijft de portefeuille-aandelen van vermogenstitels afhankelijk van het regime. Onze resultaten laten zien dat de maatstaf van Barsky e.a. (1997), hoewel deze een stevigere basis in de economische theorie heeft, weinig verklarende kracht heeft, terwijl ad hoc, meer intuïtieve maatstaven van risico-aversie aanzienlijk beter de portefeuillekeuze verklaren. We bespreken de redenen van deze bevinding.

In een recent artikel schatten John T. Warner en Saul Pletter (AER, 2001) individuele disconteringsvoeten vanuit een keuze tussen een annuïteit of een lump-sum bijdrage bij een militaire afvloeiingsregeling. Uit dit eenvoudige experiment vinden de auteurs zeer hoge schattingen van de individuele disconteringsvoet (tot 30%). In hoofdstuk 4 analyseren we een soortgelijke keuze tussen een annuïteit en een lump-sum kapitaaloptie bij pensionering bij Zwitserse pensioenfondsen, hetgeen beslissingen over substantieel grotere bedragen behelst. De empirische analyse is gebaseerd op een ad hoc dataset. Gedurende het academisch jaar 2000/2001 werd contact gezocht met circa 120 grote en middelgrote Zwitserse pensioenfondsen via de post met een korte beschrijving van het onderzoeksproject. Ongeveer de helft van de geadresseerden antwoordde en 15 van hen waren bereid gegevens te verstrekken. Wegens databeperkingen en andere (technische en organisatorische) problemen kon een gegevensbestand van 9 bedrijven die, zowel publiek als privaat, actief zijn in diverse bedrijfstakken worden samengesteld. Het gegevensbestand bestaat uit 1449 waarnemingen. We vinden dat persoonlijke kenmerken (zoals geslacht, huwelijkse staat, pensioenleeftijd, aantal kinderen) bij de keuze enigszins wordt overschaduwd door andere componenten, namelijk bedrijfsspecifieke effecten en de conversiefactor, dat is de factor waarmee kapitaal in een annuïteit wordt vertaald. In tegenstelling tot de resultaten van Warner en Pleeter vinden wij dat de disconteringsvoet geen essentiële rol speelt bij het verklaren van de individuele keuze. Dit lijkt te suggereren dat mensen, als ze financiële beslissingen nemen, kiezen op basis van makkelijke variabelen (in dit geval de conversiefactor) in plaats van meer gecompliceerde en verfijnde variabelen. Deze bevinding kan worden verklaard met begrensde rationaliteit, dat de beperkte cognitieve vermogens benadrukt die de menselijke probleemoplossing beperken. Het ideaal van rationele besluitvorming vereist een keuze die een maatstaf van verwacht nut over alle eventualiteiten maximaliseert. Deze aanname lijkt te sterk om een nauwkeurige beschrijving te geven van het gedrag van realistische individuen die de economie bestudeert.

Hoofdstuk 5 richt zich op de rol van gewoontevorming bij individuele preferenties met betrekking tot consumptie en besparingen. In dit hoofdstuk schatten we een model gebaseerd op Alessie en Lusardi's (1997) gesloten-vorm oplossing van besparingen, waar besparingen zijn uitgedrukt als functie van besparingen in de vorige periode en andere regressoren, zoals leeftijd, geslacht, opleidingsniveau, gezinsconsumptie, verwachte en gerealiseerde inkomensveranderingen. Onze empirische resultaten, gebaseerd op enkele vragen van het CentER Saving Survey, laten bewijs zien voor gewoontevorming. Deze conclusie is niet in overeenstemming met sommige eerdere studies. Dynan (2000) en Guargiglia en Rossi (2001) vinden negatieve schattingen van de gewoontevormingscoëfficiënt. Hun resultaten komen van de Euler vergelijking voor consumptie in plaats van een gesloten-vorm oplossing. Wij beargumenteren dat de data die zij gebruiken in hun analyse betrekking hebben op consumptie-uitgaven (in plaats van besparingen), hetgeen waarschijnlijk met aanzienlijke fouten is gemeten. Zulke meetfouten zouden verantwoordelijk kunnen zijn voor een sterk irreële negatieve correlatie tussen verschillen in huidige (Δc_{it}) en eerdere consumptieniveau's (Δc_{it-1}). Bijgevolg is de OLS-schatting van de gewoontevormingsparameter γ geneigd een negatieve waarde aan te nemen. Bovendien is een tweede reden om de gesloten-vorm oplossing te gebruiken als basis voor het empirische model dat het meer informatie over het gewoontevorming-model bevat dan de Euler vergelijking. Daarom staat de gesloten-vorm oplossing een krachtigere test van de validiteit van het gewoontevorming-model toe dan de Euler vergelijking benadering. Voorts vinden we bewijs van een korte planningshorizon en liquiditeitsbeperkingen. Meer theoretisch onderzoek lijkt nodig om de gezamenlijke invloed van liquiditeitsbeperkingen en gewoontevorming te onderzoeken.

Samenvattend, in de meeste empirische bevindingen beschreven in dit proefschrift bevestigen de data de voorspellingen van het rationele-keuze model. Echter, we vinden soms ook dat feitelijk gedrag (ten minste gedeeltelijk) afwijkt van zulke voorspellingen, zodat de beperkte rationaliteit een betere verklaring lijkt te geven voor feitelijke individuele besluitvorming: wanneer keuzes van mensen afwijken van de aannames van de rationele theorie, dan dient economisch onderzoek naar besluitvorming concepten uit andere disciplines over te nemen die empirisch contra-intuïtieve bevindingen verklaren.