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Household Portfolios and Implicit Risk Aversion

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HOUSEHOLD PORTFOLIOS AND IMPLICIT RISK AVERSION*

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Abstract

We derive from a sample of US households the distribution of the risk aversion implicit in their portfolio choice. Our estimate minimizes the distance between the certainty equivalent return generated with observed portfolios and portfolios that are optimal in a mean-variance framework. Taking into account real wealth and constraints in portfolio composition, we obtain a median risk aversion coefficient of 2.7 and observe substantial heterogeneity across households. Our analysis informs that risk aversion reduces with wealth and education, and increases with age. Disregarding real wealth and constraints, our estimates are markedly larger and the direction of the above correlations differs. The inferred optimization bias is small, especially with over-simplified portfolios.

Keywords: risk aversion, portfolio choice, real wealth, housing, constraints.

JEL classification codes: D81, G11, D14.

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1. Introduction

Neoclassical economic models typically assume that individuals make their choices maximizing a utility function conditional on their preference parameters. Among these parameters, the risk aversion (RA) is crucial when uncertainty is a concern. In this paper we provide an estimate of the RA coefficient based on the portfolio allocation of US households, and under different assumptions on wealth and constraints on portfolio weights. The link between portfolio choice and risk aversion has been widely explored in the literature, starting with the seminal works of Cohn et al. (1975) and Friend and Blume (1975)[1]. These works base their analysis on the portfolio share held in risky assets, under various definitions of wealth and risky assets.

Our work departs from the existing literature in three directions. First, we consider a more detailed definition of portfolio, with a distinction between deposits (risk free), bonds, stocks, and real assets. Earlier studies assume that bonds and stocks face the same risk, although it is common knowledge that stock returns have been historically more volatile. We also consider real assets and related liabilities, as their size in real household portfolios is not negligible. Residential housing accounts for more than two thirds of the average portfolio of US households (Flavin and Yamashita, 2002); similarly, mortgage debts for the primary residence are by far the largest type of liability. Ignoring real wealth may bias our analysis, since house price risk generates hedging needs (Flavin and Yamashita, 2002; Pelizzon and Weber, 2008) and crowds out stock holdings (Cocco, 2005).

Second, we allow for constraints on portfolio weights. These may be relevant especially for real assets. Individuals may indeed hold residential housing for consumption as well as investment purposes (Cocco, 2005). To correct for the potential bias due to the housing consumption motive, we follow Flavin and Yamashita (2002) and take the holding of residential housing as fixed in our static model. An optimizing agent in our problem thus chooses the portfolio allocation conditional on the wealth held in residential housing. We complete our analysis of market imperfections including three further constraints. We require that liabilities cannot exceed the value of real assets. We also consider short-selling restrictions in deposits, bonds and stocks. Short-selling in financial markets is not prohibited, but discouraged by the fact that proceeds are not normally available to be invested

[1] Other empirical works in the context of portfolio choice are McInish (1982), Siegel and Hoban (1982), Morin and Suarez (1983), Riley and Chow (1992), and Shaw (1996).

elsewhere. This is enough to eliminate a private investor with just mildly negative beliefs (Figlewski, 1981).

The last departure from the literature of our approach is that we allow for a potential difference between observed and mean-variance efficient portfolios. This difference may be due to investor's mistakes, or wrong model assumptions. Our estimate is derived from the comparison between observed and mean-variance efficient portfolios. For each portfolio we observe, we first derive the optimal alternative portfolio in a uniperiodal mean-variance framework with constraints. We then compute the Certainty Equivalent Return (CER) generated with observed and optimal portfolios. We finally estimate the RA coefficient as the one that minimizes the distance between the two CERs. This strategy is robust to potential deviations from mean-variance efficient behavior due to wrong model assumptions or investor's mistakes.

We estimate risk aversion for a representative agent and separately for each household in our sample, drawn from the wave 2004 of the US Survey of Consumer Finances (SCF). We check the sensitivity of our findings to the exclusion of real wealth, constraints, and to different time series of asset returns. The standard practice of estimating the coefficient for a representative agent may omit important sources of heterogeneity that are not orthogonal to other observed household characteristics. Our dataset allows us to investigate this issue. Since portfolio composition varies widely within our observations, we expect to observe heterogeneity in risk aversion with respect to socio-demographic characteristics.

Our results are of potential interest to economists, who have long posited models in which risk aversion plays a key role. Understanding individual attitudes toward risk is intimately related to the goal of predicting economic behavior. Our findings may also be of interest to financial advisors. The evidence of a robust difference in risk attitudes by socio-demographic characteristics can be used to design products better suited to investors' preferences. An age profile for risk aversion could also have important implications, at the macro-economic level, for an ageing society. If elderly individuals are predicted to be more risk averse, a more conservative population could substantially influence macroeconomic performance and political outcomes.

The remainder of this paper is organized as follows. Section 2 surveys the literature on risk aversion measurement. Section 3 presents the framework we consider. Section 4 describes our survey data (SCF) and time series data (covering quarterly the years 1980-

2004). Section 5 reports our estimates of the coefficient of risk aversion and the inferred optimization bias, i.e. the minimum distance between the two CERs. We first consider the case of a representative agent and then the distribution in our sample. Finally, Section 6 concludes. In the appendix we replicate our exercise with different estimates of the moments of the asset returns.

2. Previous estimates of the coefficient of risk aversion

Empirical research has addressed in various contexts the size of risk aversion and its relationship with economic and, more recently, socio-demographic variables. The size of the RA coefficient is still an empirical issue, and its estimate varies widely with the data and the specific environment studied. Farber (1978) estimates a risk aversion of at least 2.5 from collective bargaining agreements. Estimates from aggregate consumption data in Hansen and Singleton (1983) lie between 0 and 2. Values between 1.2 and 1.8 are found in Szpiro (1986) from time series data on property/liability insurance. Pindyck (1988) obtains an estimate of risk aversion between 1.6 and 5.3 from a structural model of equity pricing. Halek and Eisenhauer (2001) estimate the coefficient of risk aversion from data on life insurance purchases, obtaining a mean of 3.7 and a median of 0.9.

The availability of good quality survey datasets allowed to study the heterogeneity of risk aversion across households. Some analyses are based on hypothetical survey questions, asking to compare different lotteries. From the answer to such questions it is possible to infer a degree of risk aversion. Barsky et al. (1997) use US Health and Retirement Study data and find substantial heterogeneity across individuals aged between 51 and 61. Similar analyses are performed in Donkers et al. (2001) and Guiso and Paiella (2004), using Dutch and Italian data respectively. New frontiers in research on risk aversion involve the use of laboratory experiments (Schubert et al., 1999; Choi et al., 2007), or the combination of field experiments and hypothetical survey questions (Dohmen et al., 2006).

The heterogeneity of risk aversion in microdata on portfolio allocation has also been explored extensively. Existing studies consider the proportion of portfolios allocated to risky assets as inversely related to risk aversion. Special attention has been drawn to the link between this measure and wealth. The relationship seems to depend crucially on the definition used for wealth. Research focusing on financial wealth seems to support a negative link with risk aversion (Friedman, 1974; Cohn et al., 1975; Riley and Chow, 1992; Shaw, 1996), at least until a large threshold, reflecting the empirical evidence of stock holdings increasing in wealth (see Guiso et al., 2001). Friend and Blume (1975) also find evidence of a negative relationship from a precursor of the current SCF, but only when owner-occupied housing is not included in their definition of wealth. Siegel and Hoban (1982) find from US National Longitudinal Survey data patterns consistent with decreasing or constant risk aversion using narrow definitions of wealth, and patterns consistent with increasing risk aversion using broader definitions of wealth, including housing and non-marketable assets. Morin and Suarez (1983) draw similar conclusions using the Canadian Survey of Consumer Finances and including human capital in the definition of wealth. Shaw (1996) focuses on the effect of human capital, and finds from SCF data a negative correlation with risk aversion.

A more recent strand of literature investigates the link between risk aversion and some household socio-demographic characteristics, in different contexts. In general, there seems to be consensus on the relationship between risk aversion, gender and education. Men and more highly educated individuals have been found to exhibit a lower risk aversion (see in particular Riley and Chow, 1992, and Halek and Eisenhauer, 2001). There is instead no consensus with regards to other variables, such as race, health, marital and job status. The most important relationship is probably with age. While the majority of the empirical studies have found that risk aversion rises with age (see McInish, 1982; Morin and Suarez, 1983), some works fail to support this view, or observe a non-linear trend. Riley and Chow (1992), for instance, find a risk aversion declining until age 65. Barsky et al. (1997) observe higher risk aversion in the middle of the adult age.

With this paper we aim to shed further light on household risk aversion, and its link with wealth, age and other demographic variables.

3. The model

In the mean-variance model of Markowitz (1952), the investor optimizes the trade-off between the mean and variance of portfolio returns. Without loss of generality, our endowment is given by one risk free asset (with return r_0) and a set of n risky assets with vector of expected excess returns η and covariance matrix Σ. In this framework, an optimizing agent with risk aversion $\gamma > 0$ chooses the portfolio $w^* = \begin{bmatrix} w_1^* & w_2^* & \dots & w_n^* \end{bmatrix}'$ that solves the problem

$$\max_w \left\{ w'\eta + r_0 - \frac{1}{2}\gamma w'\Sigma w \right\} \tag{1}$$

subject to inequality constraints on portfolio composition,

$$l \le w \le u \tag{2}$$

The objective function (1) is known as the Certainty Equivalent Return (CER) for the expected utility of a mean-variance estimator. It is common practice to call it simply CER, as it also approximates the CER of a myopic investor with quadratic utility functions.

It is well known that, in the absence of constraints, the optimal portfolio weights are given by

$$w^* = \frac{1}{\gamma}\Sigma^{-1}\eta \tag{3}$$

We believe, however, that constraints are important for investors' portfolio allocation. Constraints on real assets are especially relevant to deal with the consumption motive that influences the holding of residential housing. To reduce the effect of the consumption motive, Pelizzon and Weber (2007) adjust household portfolios reducing real wealth holdings by an imputed present value of future rents. In our static framework we instead follow Flavin and Yamashita (2002) and Pelizzon and Weber (2008), and assume that households choose the allocation of wealth *conditional* on their holding $\overline{w}_c$ of residential housing. Suppose that households have no access to real assets other than housing. Disregarding other constraints, optimal weights in the reduced portfolio allocation problem are given by

$$w_u^* = \frac{1}{\gamma}\Sigma_u{}^{-1}\eta_u - \Sigma_u{}^{-1}\mathrm{K}_{uc}\overline{w}_c \tag{4}$$

where weights and moments relative to unconstrained (financial) assets are denoted by subscript u, and K_{uc} is the covariance between the returns of unconstrained and constrained assets. Comparing equation (4) with (3), optimal portfolio allocation accounts for an additional hedge term that depends neither on the expected value nor on the riskiness of the return of the primary residence. In our empirical exercise we consider portfolios with or without real assets, and with or without constraints on portfolio composition. Constraints are: no short sale in deposits, bonds and stocks; no mortgage financing for more than the value of real assets (that is, bonds cannot take a position below the opposite of real assets); investment in real assets not lower than the value of residential housing.

3.1. Implicit risk aversion

For each household we observe a portfolio of weights $\omega = \left[\omega_1 \quad \omega_2 \quad \ldots \quad \omega_n \right]'$. The comparison between observed and optimal portfolios is often made in terms of CERs (see DeMiguel et al., 2008). Define the distance between the CER of optimal and observed portfolios as:

(5) $$\Delta(\gamma) = \max_w \left\{ w'\eta - \frac{1}{2}\gamma w'\Sigma w \right\} - \left(\omega'\eta - \frac{1}{2}\gamma \omega'\Sigma \omega \right) \geq 0$$

subject to constraints (2). We derive our measure of implicit risk aversion as the value of γ that minimizes $\Delta(\gamma)$; we call optimization bias $\rho = \min_\gamma \Delta(\gamma)$ the minimized objective function. The sample counterpart of (5) is

(6) $$D(\gamma) = \max_w \left\{ w'e - \frac{1}{2}\gamma w'Sw \right\} - \left(\omega'e - \frac{1}{2}\gamma \omega'S\omega \right)$$

where (e,S) consistently estimate the true asset return moments (η, Σ). We estimate the implicit risk aversion parameter as:

(7) $$\hat{\gamma} = \arg\min_\gamma \left\{ D(\gamma) \right\}$$

If there are no restrictions, optimal portfolio weights are given by the sample counterpart of equation (3) and the implicit risk aversion parameter is

(8) $$\hat{\gamma}_0 = \left(\frac{e'S^{-1}e}{\omega'S\omega} \right)^{1/2}$$

with optimization bias

(9) $$\hat{\rho}_0 = \left(e'S^{-1}e \right)^{1/2} \left(\omega'S\omega \right)^{1/2} - \omega'e$$

When constraints (2) are also present, a closed-form solution is not available, and the optimal risk aversion γ_1 is implicitly defined in the equation

(10) $$w^*(\gamma_1)' Sw^*(\gamma_1) = \omega'S\omega$$

that requires that the risk associated to optimal and observed portfolios is the same.

4. Data

4.1. Portfolios

Our data on household portfolio holdings are taken from the wave 2004 of the Survey of Consumer Finances (SCF). The SCF collects detailed information on assets and liabilities, including home ownership and mortgages, for a cross-section of US households (4,519 in the wave 2004). The SCF data are used by Bucks et al. (2006) to provide a detailed description of household portfolios conditional on demographic characteristics and wealth distribution. The survey design over-samples relatively wealthy households and sampling weights are provided in order to produce unbiased statistics for the US family population. The SCF handles the high rate of item non-response typical of wealth-related microdata by imputing a set of five values that represent a distribution of possibilities. Multiple imputation of missing data increases the efficiency of estimation, allowing the researcher to use all available data, and has the distinct advantage of providing information on uncertainty in the imputed values. We exploit this information as suggested in Rubin (1987): we develop our analysis independently for each of the five completed datasets and our final statistics are the average of the estimates derived for each dataset.

We consider two definitions of wealth. The first – financial wealth - includes the main financial assets. We aggregate portfolio holdings in three categories: deposits, bonds, and stocks. The second definition – total wealth - includes also real estate, other real properties (aggregated in the fourth category real assets), and their related liabilities. The size and the empirical distribution of household wealth changes markedly using either definition (Figure 1). While we find a median value of 56,200 USD looking at total wealth, the median is only 11,060 USD using the narrower definition which refers only to financial wealth.

Table 1 reports the aggregate portfolio in our dataset, computed accounting for multiple imputations and sampling weights. The SCF is exceptionally good in giving detailed information on composite assets. With regards to mutual funds, we know whether they are tax-free, bond, balanced, stock or other funds and group them accordingly. We arbitrarily assume that balanced and other funds are equally weighted in bonds and stocks. This assumption is however not crucial as the size of these assets in household's portfolio is negligible in most cases. For four assets (IRA-Keogh accounts, retirement accounts, annuities, and trust-managed accounts) we know how they are invested, and group them as deposits (if invested in "interest-earning assets"), bonds (if in "annuities or other assets"), stocks (if in “stocks”, “hedge funds”, or “mineral rights”). If such assets are invested in “stocks and other assets”, the SCF asks the fraction invested in stocks. In this case we assign this fraction to stocks and what is left to bonds. It is worth noting, however, that these four assets are commonly tax-reduced, tax-deferred, or tax-free by statute. This bonus gives rise to an actual return that is higher than the one we assume. A similar concern arises with liabilities. In our analysis we include liabilities in the bond category, after noticing that mortgages rates and interest rates on bonds are linked to similar fundamental economic variables. 87.14 percent of the households having a mortgage report that they took it out to renegotiate an earlier loan, and 17.59 percent of the remaining ones report that they have an adjustable mortgage rate. Therefore, we interpret the mortgage rate of our observed portfolios as variable.

After dropping the households with missing information or negative wealth, the sample consists of 4,193 observations on household socio-demographic and economic characteristics. Considering total wealth, the largest share (70.63 percent) is held in real assets, mostly in residential housing (51.67 percent). The inclusion of mortgages in the analysis determines a short position in bonds. From the table we also observe that most financial wealth is held in stocks.

In a mean-variance framework households holding only deposits are characterized by infinite risk aversion. We therefore drop from our estimation sample 1,241 (560) households for which financial (financial and real) wealth is held only in deposits in at least one imputation. We exclude more observations when we restrict our attention to financial wealth, as several households hold only deposits and residential housing. Table 2 reports the composition of total wealth in our sample by portfolio type.

4.2. Time series

Our yearly financial returns (bonds and stocks) are computed from Datastream time series of US asset total return indices. The series are “Merrill Lynch US Corporate & Government Master Index”, and “MSCI USA Stock Index”.

It is more problematic to find a time series of real asset returns valid for our purpose. We choose the “MIT-CRE Transaction-based Index of US Real Estate Investment”[2]. This index, measured since 1985 on a quarterly frequency, is based on transaction prices to

[2] Downloadable from http://web.mit.edu/cre/.

avoid sources of index smoothing and lagging bias that are present in other indices (see Fisher et al., 2007). The total return index we use incorporates returns from both property value and property cash flow in the apartment, industrial, office, and retail sectors.

We compute excess returns as returns net of the yield return of 3-month US T-bills (considered as risk-free). Using the largest period available for all series (from 1985 to 2004 on a quarterly frequency), real asset returns are dominated in a mean-variance sense by bonds. This may potentially bias our estimates. To overcome this problem, one possibility is to consider a shorter period. This case is discussed in the appendix. In our benchmark case we instead extend our time series length using the method shown in Stambaugh (1997). We exploit the same-period correlation between financial and real asset returns to predict prior realizations of real asset returns from observations of financial asset returns dating back to 1980. Our final series cover the period 1980 – 2004 (100 observations) on a quarterly frequency, and are shown in Figure 2. The T-bill average yield return over this period is 5.7333 percent. Moments and other statistics of the remaining assets are computed according to Stambaugh (1997) and reported in Table 3. We see that stocks are by far the category with the highest risk and expected excess return; their Sharpe ratio is however below the ones of bonds and real assets, that are worth about 43 percent each. Table 3 also shows the tangency portfolios in an unconstrained mean-variance framework. There are no short positions in the tangency portfolios. Compared with the aggregate portfolio from SCF (Table 1), weights are much higher for bonds, and much lower for stocks and real wealth.

5. Findings

5.1. Aggregate risk aversion

We first present a measure of risk aversion for a representative agent in our sample. We derive the RA coefficient γ and the optimization bias ρ from a characterization of equations (6), (8) and (10) using as observed portfolio the aggregate portfolio (whose average over the five imputations is shown in Table 1).

Table 4 shows our estimates. We accompany our measure with a 95 percent confidence interval from a block-bootstrap simulation (see Kunsch, 1989). We resample 1,000 times our return time series[3], stratifying in such a way to have 20 observations from the period 1980-1984 and 80 observations from the period 1985-2004. We then use the method in Stambaugh (1997) to compute moments from each time series, and estimate from each imputation the implicit RA coefficient and the optimization bias.

We estimate a risk aversion parameter for a representative agent of around 4.75 from the financial portfolio, and a risk aversion of 7.63 and 2.22 from the unconstrained and constrained total portfolio respectively. Our measure of risk aversion increases when we extend the definition of portfolio to real wealth, and gets a more reasonable value when constraints are taken into account. The optimization bias of the aggregate financial portfolio is 0.89 percent per year, and 0.87 (0.5) percent for the unconstrained (constrained) total portfolio. The bias of the financial portfolio is not directly comparable with the bias of the total portfolio (constrained or not), because of the different definitions of wealth they refer to. We may instead interpret the difference 0.87-0.50=0.37 as the annual percentage cost of facing constraints in total wealth allocation.

5.2. Household-specific risk aversion

Heterogeneity may be important in preference parameters. We investigate this issue estimating the risk aversion implicit in each household portfolio in our dataset. Figure 3 reports the empirical cumulative distribution function of our estimates of the implicit risk aversion derived from the unconstrained financial portfolio, γ_0^F, from the unconstrained total portfolio, γ_0^{FR}, or from the constrained total portfolio, γ_1^{FR}. When we focus on the financial portfolio, risk aversion is never lower than 2.67, and about one third of our sample lie below 5, considered a limit for plausible values in the literature. When we include real wealth, few cases are above 10 and more values are close to 0. We estimate a low γ_0^{FR} for those households who hold a large share of wealth in real estate, since this share bears a non-negligible risk. When we incorporate constraints in the analysis, γ_1^{FR} is typically lower and two thirds of our estimates lie below 5. The upper tails of the empirical distribution of γ_0^F and γ_1^{FR} are essentially the same: these households make negligible investments in stocks and real wealth apart from residential housing. Disregarding constraints, the in-

[3] We set blocks of size 2 following the optimal rule $\mathrm{int}\left(T^{1/5}\right)$ as suggested in Hall et al. (1995).

clusion of real wealth in the analysis produces estimates of the implicit risk aversion γ_0^{FR} higher than γ_0^F for 2,126 households (58.52 percent of the sample; see Table 5). When we introduce the constraints, the corresponding estimated risk aversion γ_1^{FR} is lower than γ_0^F in 2,966 cases (81.6 percent) and lower than γ_0^{FR} in 3,048 cases (83.9 percent).

To understand what forces drive this behavior, Table 5 reports the average composition of the household total portfolio when the inclusion of real wealth and constraints generates larger or smaller estimates of risk aversion. When we compare the implicit risk aversion of the financial portfolios with the one of the total unconstrained portfolios we observe that households with $\gamma_0^{FR} \le \gamma_0^F$ concentrate their wealth in real assets and are (consequently) deeply indebted. The estimate based on the constrained total portfolio is more likely to be lower than γ_0^{FR} for households with outstanding liabilities, high investment in stocks, and/or real assets different from residential housing. To illustrate the role played by the inclusion of real assets and the constraints on residential housing investments, consider the case of a household with only risk free assets and residential housing. This household is infinitely risk averse if we look at her financial portfolio (completely risk free). Yet the same household is much less risk averse if we look at her total portfolio, since a share of wealth is held in risky assets. When we introduce the constraints on residential housing our estimate of risk aversion increases, because the household holds no risky assets other than residential housing, but it is however finite because the household does not hedge against the risk associated to the constrained part of the portfolio (see equation 4).

We now compare our estimates with respect to the type of portfolio held by the households. Table 6 reports the 25th, 50th and 75th percentiles of risk aversion in the whole sample and when each constraint binds. The median risk aversion we estimate in our sample is 5.98 from the financial portfolio, 6.77 from the total portfolio, and 2.68 from the constrained total portfolio. We estimate higher risk aversion for those with holdings in deposits, few liabilities (i.e., when the constraint on bonds does not bind), and no investment in stocks. Conclusions cannot be drawn with respect to the constraint on real wealth. Among the risky components of wealth, real assets are those with the lowest variance in our data. The overall effect also depends on the remaining portfolio composition.

We perform OLS regression analysis to examine the potential effects of wealth and socio-demographic characteristics on risk aversion (Table 7). Our dependent variable is the logarithm of the risk aversion coefficient estimated from the unconstrained financial portfolio, and the unconstrained or constrained total portfolio. The first specification we consider includes a polynomial on wealth (either financial or total), a polynomial on age, household size, and a number of dummy variables on gender, marital status, race, education, financial advisor recommendations, self-assessed health status, and job characteristics. In all our regressions we find wealth to be significant at 1 percent in explaining the log of risk aversion. We also obtain a significant relationship at 5 percent between risk aversion and those who work in the finance sector. The direction of this correlation is positive when our estimate is based on the unconstrained total portfolio, and negative in the other two cases. There is no consensus in the literature on how the coefficient should vary with wealth; already Siegel and Hoban (1982) and Morin and Suarez (1983) found for the risk aversion coefficient a negative correlation with financial wealth, and a positive correlation with total wealth.

Our regressions also show a significant role for age. Risk aversion from the financial portfolio is at its minimum when the head is about 57 years-old, and always increasing with age when we compute it from the total portfolio. Although each coefficient in the polynomial on age is not significantly different from zero when we use the broader definition of portfolio, we reject the null hypothesis that both coefficients are jointly equal to zero (*F*-test: 28.22 and 43.86 in the unconstrained and constrained case respectively, with *p*-value: 0.0000). In our static model it is not clear whether these findings are indicative of real variations in risk aversion, or just reflect other variations that we do not consider, such as in the planning horizon length or in the exposure to health shocks. Depending on the measure we consider, we find a significant effect of additional variables. When we use the financial portfolio, risk aversion is found lower when the head works in the finance sector; when we use the unconstrained total portfolio, risk aversion is lower when the head works as employee. We also find education to be significant at 1 percent in all cases but the unconstrained total portfolio. According to our preferred specification, where the risk aversion coefficient is estimated from the constrained total portfolio, risk aversion is thus higher for households with less wealth, for households whose head is older or less highly educated. We instead find differences in household size, gender, marital status, race, financial advisor, occupation, or business industry to be not significant when we control for wealth, age and education.

Since the holding of residential housing is driven by a consumption as well as investment motive, we study a second specification, where we include the ratio of home equity to total wealth among the regressors when the dependent variable is derived from the financial and real portfolio. The coefficient of the new covariate is always significant at the 5 percent level and negative, and the findings obtained with the first specification are still confirmed.

Table 8 informs on the relation between our estimate of risk aversion and a self-assessed measure of risk aversion elicited by the SCF questionnaire. More precisely, we exploit the following question:

> «Which of the following statements comes closest to describing the amount of financial risk that you [and your husband/wife/partner] are willing to take when you save or make investments?»

which takes as possible answers

1. Take substantial financial risks expecting to earn substantial returns
2. Take above average financial risks expecting to earn above average returns
3. Take average financial risks expecting to earn average returns
4. Not willing to take any financial risks

We consider as little risk averse households who respond 1 or 2, and highly risk averse households who respond 3 or 4. If our strategy is correct, our estimated implicit risk aversion should be consistent with households' self-assessment. Our estimated γ_1^{FR} are indeed fully consistent with the information provided directly by the respondents: the implicit risk aversion is higher for households who self-classify themselves as highly risk averse, and this relation holds also conditional upon age class.

In the appendix we replicate our study using return time series that generate very different estimates of the moments, and find that the choice of the time series may affect the size of our risk aversion estimates, but not their relationship with household characteristics.

5.3. Optimization bias

With the implicit risk aversion we compute $\hat{\rho} = D(\hat{\gamma})$, the optimization bias defined in section 3. This measure describes the distance between observed and theoretically optimal portfolios, and is inversely related to risk aversion. To understand this relationship, consider the extreme case of households with risk free portfolios. In our framework, the difference between the CER of the actual and the optimal portfolios ($\Delta(\gamma)$ in equation (5)) is minimized by an infinite risk aversion coefficient and a risk free optimal portfolio. Since observed and optimal portfolios coincide, the bias is equal to 0. The same difference for households with holdings in risky assets, instead, is minimized by a finite risk aversion coefficient and an optimal portfolio that does not necessarily coincide with the observed one. The bias is then higher. In general, the more risk averse the household, the smaller the space of asset combinations feasible for the optimal portfolio, and so the smaller the optimization bias.

Using the aggregate portfolio, the bias we estimate for a representative agent is 0.89 percent per year with the financial portfolio, and 0.87 percent with the total portfolio; it reduces to 0.5 if we consider constraints to portfolio composition (see Table 4). When we compute this measure for each observation in our sample, our median values are 0.37, 1.42, and 0.25 percent respectively. We however observe in Figure 4 that heterogeneity in household behavior is not negligible, at least when we focus on the unconstrained total portfolio. Estimates are larger when we include real wealth in our definition, and neglect constraints. When we consider constraints the bias reduces markedly, and our estimates are in most cases below 1 percent (this happens for 86.67 percent of the households).

In the following we focus on the bias measure based on total wealth with the constraint on residential housing. Table 9 reports the percentiles of the individual estimates by observed portfolio composition. We see that the bias is lower - 0.15 percent - when the constraint on real wealth is binding (that is, real wealth includes only the primary residence) or when households do not hold stocks (0.17 percent). The median value is instead at its maximum for those households whose debt equals the value of their real assets.

The optimization bias increases when observed and optimal portfolios differ markedly. Table 10 reports summary statistics of the bias when each observed portfolio share is below 25 percent or above 125 percent of its optimal counterpart. Observed portfolios more frequently hold larger shares of deposits, and small shares of stocks. The table informs that, when there is a sizeable difference between observed and optimal portfolio shares, the optimization bias is typically large. The difference between the two portfolios is accrued when either the observed portfolio is poorly diversified, or the optimal portfolio includes holdings in all the asset markets. This second situation is inversely related to risk aversion. In our framework households with more conservative portfolios are associated to a higher risk aversion parameter. When risk aversion is higher, the choice of the optimal portfolio is made excluding the riskiest alternatives. This reduction of the space of feasible portfolios leads to optimal portfolios that cannot be more efficient than those with lower risk aversion coefficients. Hence the optimization bias obtained from the comparison between observed and optimal portfolios is not higher than that of less risk averse households. This situation is more frequent when we estimate constraints in the portfolios of, for instance, less wealthy households or households whose head is less highly educated. For this reason sophistication, as measured for instance by wealth or education, has a counterintuitive effect on the optimization bias. The bias of less sophisticated agents is smaller not because such agents are investing in a portfolio with a higher performance, but because their optimal portfolio is less efficient.

6. Concluding remarks

In this paper we provide new evidence on the distribution of risk aversion across households. We propose an estimation strategy for the risk aversion coefficient based on the level that minimizes the difference between the certainty equivalent return of the optimal mean-variance portfolio and corresponding to the actual portfolio held by the household. This strategy is robust to potential deviations from mean-variance efficient behavior due to wrong model assumptions, or investor's mistakes. We apply this strategy to US SCF data under several definitions of portfolio. In our preferred definition wealth includes financial and real components, and households face constraints on portfolio composition. They cannot borrow against financial assets and they must take as fixed the holding of residential housing. Additionally, they cannot take mortgages that exceed the value of their real assets. By doing so we take into account that not only investment motives, but also consumption motives are relevant in the housing tenure choice. With this constraint we therefore take the holding of residential housing as exogenous in our static model.

Our estimates of the preference parameter take plausibly small coefficients and show substantial heterogeneity across individuals. The median risk aversion coefficient equals 2.68, and 63.32 percent of the households lie below 5. Many of the correlations between risk aversion and the observable characteristics of the households are intuitive. In particular we find a lower risk aversion for wealthier households, or when the head is young, or more highly educated; the direction of the correlations is however different when we ignore constraints (risk aversion increases with wealth) or constraints and real wealth (risk aversion decreases up to age 57). In these cases our implicit risk aversion coefficients are also markedly higher, suggesting that analyses that ignore real wealth and portfolio constraints may give rise to a large bias. Although we find several strong correlations, the direction of causality is difficult to ascertain for some variables, such as unemployment, wealth, and education. These variables may not only affect an agent's risk aversion, but also be affected by it. Our estimates are however robust in indicating that gender, race, marital status, and household size do not play a significant role once we control for other variables. In the appendix we replicate our study using different time series of asset returns, and find that the choice of the time series may affect the size of our risk aversion estimates, but not their relationship with household characteristics.

We also provide evidence on the monetary loss caused by actual portfolios, conditional on the level of risk aversion. This optimization bias is worth 0.4990 percent per year for a representative agent, and 0.2509 percent per year for a median household, with 87.11 percent of households having a bias below 1 percent. The bias is lower for households with severely constrained (and simplified) portfolios. More risk averse households are those who show a smaller bias between observed and optimal portfolios. The bias is larger when we ignore real wealth and constraints on portfolio weights.

Our approach is based on several standard assumptions. We group our assets in few categories. Doing so, we neglect the tax advantages of some instruments. For instance, we ignore that loan interests are tax deductible, and that capital gains from real estate are tax free after three years. One major drawback of our analysis is that we ignore the effect of human capital. We do not attempt to derive crude estimates of human capital, as it is likely to be affected by severe measurement errors. It is however plausible that this wealth component affects risk aversion. Shaw (1996) finds human capital to be an inverse function of risk aversion in a portfolio choice problem. In our setting, human capital would enter in the optimization problem as a constraint, in a way similar to residential housing. Since older persons have lower income potential, human capital decreases with age. The effect of this component on wealth should thus be more relevant for young investors.

There are at least two main directions for future research. The analysis of the links between risk aversion, wealth and observable characteristics deserves further efforts in order to solve the problems of reverse causality and determinants of sub-optimality discussed above. Particular care should be given to age. In our static model, the significant relationship we find with age might reflect variations in the investor's planning horizon length. From the theoretical point of view it is interesting to evaluate the possibility to apply our approach in a multiperiod framework, closer to the life-cycle models of asset allocation. This will allow to disentangle risk aversion from the planning horizon length.

A. Robustness check on the moments of the asset returns

We are concerned that our findings may change using different moments of the asset returns. For this reason we check the robustness of our results to a different length of the asset return time series. We draw similar conclusions if we use different asset return indices.

We choose a time series length for which no asset return is dominated in a mean-variance sense, and the first and second moments are very different from those of Table 3. Our new time series cover quarterly the period 1990-2004 (60 observations). With these data we do not need to correct the moments using the method shown in Stambaugh (1997). Time series statistics are reported in Table 11. Compared with Table 3, real asset returns are now associated to higher expected excess returns and standard deviations than bonds. We also estimate weaker correlations, in particular a negative correlation between bonds and stocks. This produces a tangency portfolio that is more heavily invested in bonds.

Using these moments we obtain the risk aversion parameter and optimization bias estimates shown in Tables 12 and 13. From the aggregate portfolio we get a risk aversion coefficient equal to 9.65, ignoring real wealth, and to 13.69 (unconstrained) or 2.16 (constrained) including real assets. The confidence interval we report is larger than in the benchmark case of Table 4 because bootstrap simulations are based on a shorter time series (with 60 observations rather than 100). Unconstrained estimates are larger than in the benchmark case, while the constrained estimate is comparable with the results we show in the main text. The associated optimization bias is worth 3.08, 2.60, and 0.44 percent per year respectively. Also here, only the number we get in the constrained case is similar to the one we obtained previously.

Computing the risk aversion coefficient from each portfolio, we obtain a median of 15.49 using the narrower definition of wealth, and a median of 12.52 (2.96) using the broader definition of wealth and excluding (including) constraints (Table 13). The choice of the moments of the asset return may therefore change markedly the size of our estimates, but this variation is lower when we consider the constrained case. This result has to do with the fact that constraints help reduce potential errors in measurement of the efficient portfolio (Green and Hollifield, 1992). We are however primarily interested in the correlations between risk aversion and household characteristics. Table 14 reports the output of an OLS regression analogous to Table 7. We find the same variables to be significant in the various cases we examine; their marginal effect on the risk aversion coefficient have the same sign as with our benchmark estimates. In the constrained case we also find the dummy variable indicating a fair or poor health status to be significant at 1 percent and positively correlated with risk aversion. The link between the optimization bias and household characteristics is also similar to our previous findings, and we still observe a negative relationship with the risk aversion coefficient.

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Table 1. Aggregate portfolio composition (SCF 2004)

Category	Aggregate share in SCF	
	Financial	**Financial + Real**
Deposits		
Checking accounts	0.0569	0.0274
Savings and money market accounts	0.0863	0.0416
Call accounts at brokerages	0.0123	0.0059
IRA-KEOGH accounts	0.0220	0.0106
Retirement accounts	0.0078	0.0037
Annuities	0.0088	0.0042
Trust-managed accounts	0.0132	0.0063
TOTAL	**0.2073**	**0.0998**
Bonds		
Certificates of deposits	0.0437	0.0210
Savings bonds	0.0064	0.0031
Directly held corp. bonds	0.0638	0.0307
Tax free mutual funds	0.0168	0.0081
Govt. bond mutual funds	0.0054	0.0026
Other bond mutual funds	0.0103	0.0049
½ Balanced mutual funds	0.0063	0.0031
½ Other mutual funds	0.0059	0.0028
IRA-KEOGH accounts	0.0567	0.0273
Retirement accounts	0.0077	0.0037
Annuities	0.0084	0.0041
Trust-managed accounts	0.0187	0.0090
Life insurances (cash value)	0.0340	0.0164
Mortgages on primary residence (-)	-	-0.1459
Lines of credit on primary residence (-)	-	-0.0046
Loans on other real wealth (-)	-	-0.0375
TOTAL	**0.2840**	**-0.0512**
Stocks		
Directly held stocks	0.2067	0.0996
Stock mutual funds	0.1158	0.0558
½ Balanced mutual funds	0.0063	0.0031
½ Other mutual funds	0.0059	0.0028
IRA-KEOGH accounts	0.1105	0.0532
Retirement accounts	0.0187	0.0090
Annuities	0.0126	0.0061
Trust-managed accounts	0.0322	0.0155
TOTAL	**0.5087**	**0.2450**
Real assets		
Residential housing	-	0.5167
Other real assets	-	0.1896
IRA-KEOGH accounts	-	0
Retirement accounts	-	0
Annuities	-	0
Trust-managed accounts	-	0
TOTAL	**-**	**0.7063**

Number of observations: 4193.

Table 2. Average portfolio by portfolio type (SCF 2004)

	Obs.	Average total portfolio weights: Deposits	Bonds	Stocks	Real Assets	Residential housing
Deposits						
= 0	51	0	-0.0022	0.0961	0.9061	0.8460
> 0	3582	0.0974	-0.0555	0.2450	0.7132	0.5222
Bonds						
< 0	1654	0.0971	-0.4633	0.1953	1.1709	0.8515
= 0	364	0.1577	0	0.1065	0.7358	0.5929
> 0	1615	0.0894	0.1858	0.2920	0.4328	0.3144
= - real assets	72	0.4013	-1.3336	0.5987	1.3336	1.0963
> - real assets	3561	0.0968	-0.0542	0.2442	0.7131	0.5225
Stocks						
= 0	1238	0.1255	-0.2952	0	1.1697	0.9670
> 0	2395	0.0914	-0.0072	0.2938	0.6260	0.4338
Real assets						
= primary residence	2196	0.1134	-0.0933	0.2462	0.7337	0.7337
> primary residence	1437	0.0832	-0.0229	0.2432	0.6966	0.3424
Binding constraints						
At least one	2456	0.1119	-0.1031	0.2172	0.7740	0.7088
No binding constraint	1177	0.0808	-0.0031	0.2746	0.6476	0.3191
Whole sample	**3633**	**0.0971**	**-0.0554**	**0.2446**	**0.7137**	**0.5231**

Average portfolios exclude observations with risk free portfolios. "Residential housing" is included in the "Real assets" share.

Table 3. Excess return time series statistics

	Excess return (%)	Std dev (%)	Sharpe ratio (%)	Tangency portfolio: Financial	Tangency portfolio: Financial + real
Bonds	3.7295	8.7109	42.8143	0.7891	0.4194
Stocks	5.3191	17.6156	30.1956	0.2109	0.0843
Real assets	3.1629	7.4082	42.6944	-	0.4963

Covariances (%)	Bonds	Stocks	Real assets
Bonds	0.7588	*26.6493*	*19.4222*
Stocks	0.4089	3.1031	*24.4837*
Real assets	0.1253	0.3195	0.5488

Correlations in italic.

Table 4. Estimates from aggregate portfolios

	Financial portfolio: Unconstrained	Total portfolio: Unconstrained	Total portfolio: Constrained
Risk aversion	4.7460	7.6281	2.2202
	(2.7192, 7.7483)	(4.5930, 13.3010)	(0.0341, 9.4104)
Optimization bias (%)	0.8977	0.8749	0.5002
	(0.0202, 3.4849)	(0.1787, 2.6331)	(0.1419, 1.5238)

95 percent confidence intervals in parentheses are based on 1,000 block-bootstrap simulations.

Table 5. Assumptions on portfolio choice and risk aversion estimates

	Obs.	Average total portfolio weights: Deposits	Bonds	Stocks	Real Assets	Constraint: Residential housing
Inclusion of real wealth:						
$\gamma_0^{FR} \le \gamma_0^{F}$	1507	0.1481	-0.4425	0.0367	1.2576	0.9375
$\gamma_0^{FR} > \gamma_0^{F}$	2126	0.0780	0.0895	0.3234	0.5101	0.3679
Inclusion of constraints:						
$\gamma_1^{FR} \le \gamma_0^{FR}$	3048	0.0853	-0.0698	0.2778	0.7066	0.4897
$\gamma_1^{FR} > \gamma_0^{FR}$	585	0.1743	0.0389	0.0266	0.7601	0.7421
Inclusion of real wealth and constraints:						
$\gamma_1^{FR} \le \gamma_0^{F}$	2966	0.0855	-0.0943	0.2746	0.7343	0.5278
$\gamma_1^{FR} > \gamma_0^{F}$	667	0.1583	0.1495	0.0868	0.6054	0.4982
Whole sample	**3633**	**0.0971**	**-0.0554**	**0.2446**	**0.7137**	**0.5231**

Average portfolios exclude observations with risk free portfolios. γ_0^{F} = estimate from unconstrained financial portfolios; γ_0^{FR} = estimate from unconstrained total portfolios; γ_1^{FR} = estimate from constrained total portfolios. The number of observations refers to the dataset of risky total portfolios.

Table 6. Risk aversion quartiles by observed portfolio type

	Obs.	Financial portfolio, Unconstrained: 25th	50th	75th	Total portfolio, Unconstrained: 25th	50th	75th	Total portfolio, Constrained: 25th	50th	75th
Deposits										
$=0$	51	5.4003	5.4003	5.4003	6.3441	6.5143	6.9652	2.0426	2.0426	6.9173
>0	3582	4.2920	6.0531	11.5100	4.2412	6.8069	8.2985	1.2261	2.7297	11.3086
Bonds										
< 0	1654	-	-	-	2.4002	4.4037	6.2166	0.8619	1.4565	2.6134
= 0	364	3.0862	3.9676	7.0571	7.6828	7.8228	8.5790	4.1638	30.1120	31.1080
> 0	1615	4.5873	6.1687	11.5860	7.3347	8.2984	9.4965	2.4033	7.4206	17.2210
= - real assets	72	-	-	-	3.2868	4.4880	8.9823	0.6031	1.0399	6.5062
> - real assets	3561	-	-	-	4.3379	6.8058	8.2739	1.2664	2.7470	11.1690
Stocks										
$=0$	1238	6.4104	11.5720	32.4020	3.3386	7.2843	8.2876	1.5252	4.2691	27.6536
>0	2395	3.7387	5.1078	7.3886	4.6762	6.6129	8.2864	1.1516	2.0669	5.1817
Real assets										
= primary residence	2196	-	-	-	3.7995	6.6009	8.2612	1.2295	2.9484	16.3304
> primary residence	1437	-	-	-	5.3828	7.1384	8.3158	1.2308	2.2528	4.5041
Binding constraints										
At least one	2456	5.4111	8.3244	21.6803	3.9612	6.7004	8.2876	1.2308	2.8950	14.3008
No binding constraint	1177	3.9764	5.2437	7.4506	5.4084	6.9825	8.2839	1.2382	2.0856	4.0988
Whole sample	**3633**	**4.3145**	**5.9851**	**11.1046**	**4.2815**	**6.7679**	**8.2864**	**1.2330**	**2.6769**	**10.9840**

The number of observations refers to the dataset of total portfolios. Binding constraints from the total portfolio are: deposits = 0, bond = real assets, stocks = 0, real assets = primary residence. Binding constraints from the financial portfolio are: deposits = 0, bonds = 0, stocks = 0.

Table 7. Determinants of the risk aversion

	Financial portfolio	Total portfolio			
	Unconstrained	Unconstrained		Constrained	
Primary residence / Wealth	-	-	-0.0070**	-	-0.0075**
			(0.0027)		(0.0032)
Wealth (millions USD)	-0.0534***	0.0194***	0.0174***	-0.0329***	-0.0349***
	(0.0084)	(0.0046)	(0.0045)	(0.0093)	(0.0093)
(Wealth (millions USD))^2	0.0002***	-0.0001***	-0.0001***	0.0001***	0.0001***
	(0.0001)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Age	-0.0467***	0.0087	0.0106	0.0088	0.0108
	(0.0112)	(0.0087)	(0.0082)	(0.0144)	(0.0141)
Age^2/100	0.0407***	0.0031	0.0010	0.0171	0.0149
	(0.0107)	(0.0073)	(0.0069)	(0.0127)	(0.0125)
Household size	0.0372	-0.03737	-0.0355*	0.0101	0.0120
	(0.0282)	(0.0229)	(0.0195)	(0.0353)	(0.0329)
Female	0.0576	-0.0184	0.0083	0.0486	0.0760
	(0.0886)	(0.0741)	(0.0672)	(0.1278)	(0.1244)
Married	-0.0237	0.0016	-0.0028	-0.0564	-0.0609
	(0.0904)	(0.0756)	(0.0679)	(0.1261)	(0.1214)
Non-white	0.0144	-0.0207	0.0070	0.0546	0.0830
	(0.0686)	(0.0543)	(0.0497)	(0.0920)	(0.0895)
College graduate	-0.1736***	-0.0411	-0.0270	-0.4105***	-0.3961***
	(0.0527)	(0.0394)	(0.0370)	(0.0715)	(0.0706)
With financial advisor	-0.0078	0.0244	0.0150	-0.0954	-0.1050
	(0.0532)	(0.0359)	(0.0342)	(0.0662)	(0.0653)
Employee	0.1222	-0.1238**	-0.1244**	-0.1093	-0.1100
	(0.0745)	(0.0583)	(0.0523)	(0.1107)	(0.1065)
Self-employed	0.1106	0.0612	0.0493	0.0134	0.0011
	(0.0861)	(0.0604)	(0.0564)	(0.1256)	(0.1230)
Business industry: finance	-0.1733**	0.0752	0.0604	-0.0993	-0.1145
	(0.0790)	(0.0693)	(0.0691)	(0.1179)	(0.1180)
Fair / poor health	0.0581	-0.0032	-0.0055	0.1401	0.1378
	(0.0701)	(0.0470)	(0.0451)	(0.0938)	(0.0929)
Constant	3.1876***	1.3276***	1.2988***	0.4681	0.4388
	(0.2828)	(0.2666)	(0.2492)	(0.4385)	(0.4228)
Minimum obs	2939	3631	3631	3631	3631
Mult. Imp. Minimum dof	38.7	17.6	19.7	94.1	44.9

The dependent variable is the log of risk aversion. Robust standard errors in parentheses. Method: OLS.
****: significantly different from 0 at 1 percent; **: at 5 percent; *: at 10 percent.*

Table 8. Implicit risk aversion by self-assessed risk aversion

Age class	Self-assessed risk aversion	
	Low	High
35 or below	1.1314	1.7334
	(143)	(319)
36 – 50	1.6970	2.1046
	(400)	(756)
51 – 65	1.7703	3.4687
	(363)	(893)
66 – 80	3.4323	8.2887
	(109)	(514)
81 or above	2.1507	16.9504
	(13)	(123)

We report the median implicit risk aversion derived from the constrained total portfolio. Number of observations in parentheses.

Table 9. Optimization bias quartiles (%) by observed portfolio type

	Obs.	25th	50th	75th
Deposits				
$=0$	51	0.0000	0.4524	0.2675
>0	3582	0.0411	0.2509	0.6419
Bonds				
= - real assets	72	0.4563	0.9910	1.4350
> - real assets	3561	0.0362	0.2432	0.6068
Stocks				
$=0$	1238	0.0001	0.1733	0.6387
>0	2395	0.0920	0.2744	0.6285
Real assets				
= primary residence	2196	0.0160	0.1530	0.4835
> primary residence	1437	0.3030	0.5855	1.0284
Binding constraints				
At least one	2456	0.0235	0.1898	0.5832
No binding constraint	1177	0.2533	0.4874	0.8153
Whole sample	**3633**	**0.0386**	**0.2512**	**0.6357**

We report the quartiles of the optimization bias derived from constrained total portfolios.

Table 10. Optimization bias quartiles (%) by allocation error

	Obs.	25th	50th	75th
Observed over optimal investment in deposits				
$\leq 1/4$	51	0.0000	0.4524	0.4524
$\in (1/4, 5/4)$	1360	0.0000	0.0774	0.3957
$\geq 5/4$	2222	0.1275	0.3759	0.7670
Observed over optimal investment in bonds				
If observed investment < 0				
$\leq 1/4$	110	0.3643	0.5932	0.7211
$\in (1/4, 5/4)$	1066	0.0810	0.2951	0.7942
$\geq 5/4$	478	0.3732	0.8348	1.3780
If observed investment ≥ 0				
$\leq 1/4$	657	0.0000	0.1002	0.5612
$\in (1/4, 5/4)$	1042	0.0078	0.0620	0.2144
$\geq 5/4$	280	0.2162	0.4524	0.5743
Observed over optimal investment in stocks				
$\leq 1/4$	1183	0.1512	0.4984	0.9417
$\in (1/4, 5/4)$	2059	0.0035	0.1086	0.3715
$\geq 5/4$	391	0.0920	0.3099	0.6557
Observed over optimal investment in real wealth				
$\leq 1/4$	318	0.3557	0.4852	0.7139
$\in (1/4, 5/4)$	2355	0.0141	0.1311	0.4352
$\geq 5/4$	960	0.4550	0.7331	1.1928
Whole sample	**3633**	**0.0386**	**0.2512**	**0.6357**

We report the quartiles of the optimization bias derived from constrained total portfolios.

Table 11. Excess return time series statistics, shorter time series

	Excess return (%)	Std dev (%)	Sharpe ratio (%)	Tangency portfolio	
				Financial	Financial + real
Bonds	4.1071	5.5717	73.7122	0.8488	0.5858
Stocks	6.3194	17.3157	36.4950	0.1512	0.0818
Real assets	4.8470	7.3955	65.5399	-	0.3324

Covariances (%)	Bonds	Stocks	Real assets
Bonds	0.3104	*-8.0597*	*6.0647*
Stocks	-0.0778	2.9983	*19.5134*
Real assets	0.0250	0.2499	0.5469

Correlations in italic.

Table 12. Estimates from aggregate portfolios, shorter time series

	Financial portfolio	Total portfolio	
	Unconstrained	Unconstrained	Constrained
Risk aversion	9.6473	13.6932	2.1583
	(5.6096, 16.3683)	(8.0350, 21.5292)	(0.0590, 13.2499)
Optimization bias (%)	3.1299	2.6375	0.4364
	(0.0787, 6.4549)	(0.7213, 5.4351)	(0.3577, 2.0956)

Note: 95 percent confidence intervals in parentheses are based on 1,000 block-bootstrap simulations.

Table 13. Estimate quartiles from household portfolios, shorter time series

	Obs.	Financial portfolio			Total portfolio					
		Unconstrained			Unconstrained			Constrained		
		25th	50th	75th	25th	50th	75th	25th	50th	75th
RRA	3633	8.5072	15.4858	28.5920	7.5761	12.5250	15.6720	1.5383	2.9638	13.6588
Optimization bias (%)	3633	0.3308	1.3355	4.2098	2.0826	3.4042	8.2475	0.0643	0.2930	0.7047

The number of observations refers to the dataset of risky total portfolios.

Table 14. Determinants of the risk aversion, shorter time series

	Financial portfolio	Total portfolio			
	Unconstrained	Unconstrained		Constrained	
Primary residence / Wealth	-	-	-0.0069**	-	-0.0066**
			(0.0027)		(0.0029)
Wealth (millions USD)	-0.0603***	0.0235***	0.0216***	-0.0651***	-0.0670***
	(0.0093)	(0.0048)	(0.0047)	(0.0104)	(0.0105)
(Wealth (millions USD))^2	0.0002***	-0.0001***	-0.0001***	0.0002***	0.0002***
	(0.0001)	(0.0000)	(0.0000)	(0.0001)	(0.0001)
Age	-0.0411***	0.0049	0.0068	-0.0115	-0.0097
	(0.0112)	(0.0086)	(0.0081)	(0.0150)	(0.0148)
Age^2/100	0.0375***	0.0060	0.0039	0.0376***	0.0356**
	(0.0109)	(0.0073)	(0.0069)	(0.0141)	(0.0140)
Household size	0.0312	-0.0361	-0.0344*	0.0188	0.0205
	(0.0233)	(0.0226)	(0.0193)	(0.0345)	(0.0322)
Female	0.1018	-0.0018	0.0247	0.0881	0.1134
	(0.0946)	(0.0764)	(0.0699)	(0.1372)	(0.1344)
Married	-0.0127	-0.0232	-0.0275	-0.1444	-0.1485
	(0.0903)	(0.0761)	(0.0686)	(0.1323)	(0.1283)
Non-white	0.0959	-0.0169	0.0107	0.0772	0.1035
	(0.0691)	(0.0543)	(0.0499)	(0.0953)	(0.0935)
College graduate	-0.2611***	-0.0568	-0.0427	-0.5438***	-0.5304***
	(0.0540)	(0.0394)	(0.0371)	(0.0748)	(0.0741)
With financial advisor	-0.0389	0.0151	0.0057	-0.1301*	-0.1390*
	(0.0541)	(0.0358)	(0.0341)	(0.0748)	(0.0743)
Employee	0.0844	-0.1632***	-0.1638***	-0.1486	-0.1492
	(0.0811)	(0.0599)	(0.0543)	(0.1186)	(0.1162)
Self-employed	0.0996	0.0211	0.0093	-0.0089	-0.0202
	(0.0934)	(0.0619)	(0.0581)	(0.1372)	(0.1359)
Business industry: finance	-0.1829**	0.0671	0.0522	-0.0859	-0.1001
	(0.0788)	(0.0675)	(0.0671)	(0.1189)	(0.1189)
Fair / poor health	0.0626	-0.0101	-0.0124	0.1917*	0.1895*
	(0.0697)	(0.0465)	(0.0445)	(0.1030)	(0.1025)
Constant	3.8556***	2.1149***	2.0864***	1.3765***	1.3493***
	(0.2751)	(0.2679)	(0.2504)	(0.4127)	(0.4020)
Minimum obs	2921	3626	3626	3624	3624
Mult. Imp. Minimum dof	37.3	16.2	17.7	15.9	15.0

The dependent variable is the log of risk aversion. Robust standard errors in parentheses. Method: OLS.
****: significantly different from 0 at 1 percent; **: at 5 percent; *: at 10 percent.*

Figure 1. Household wealth empirical cumulative distribution (SCF 2004)

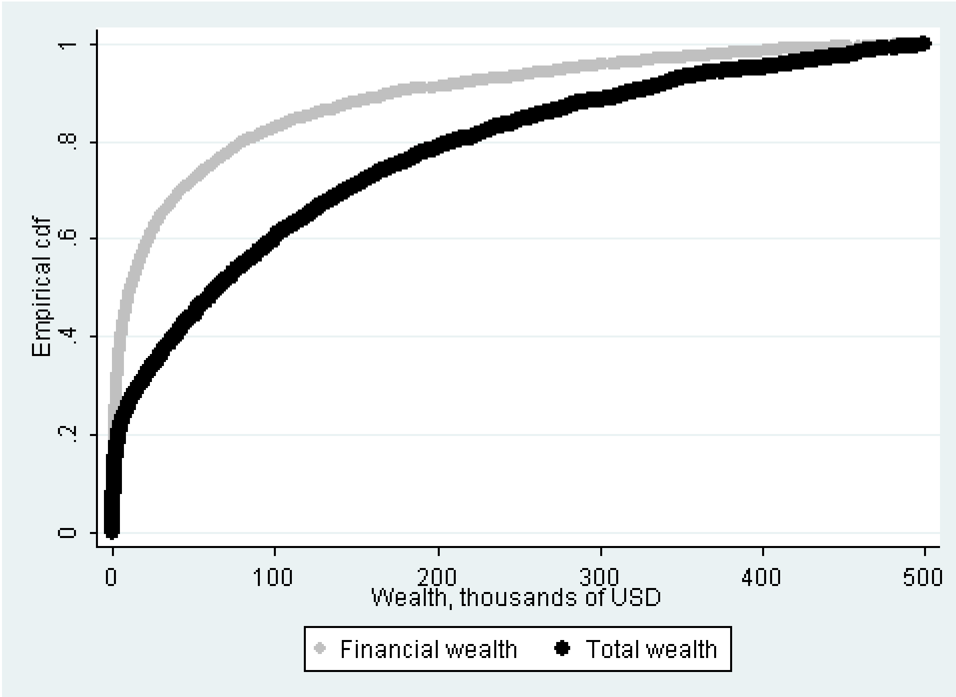
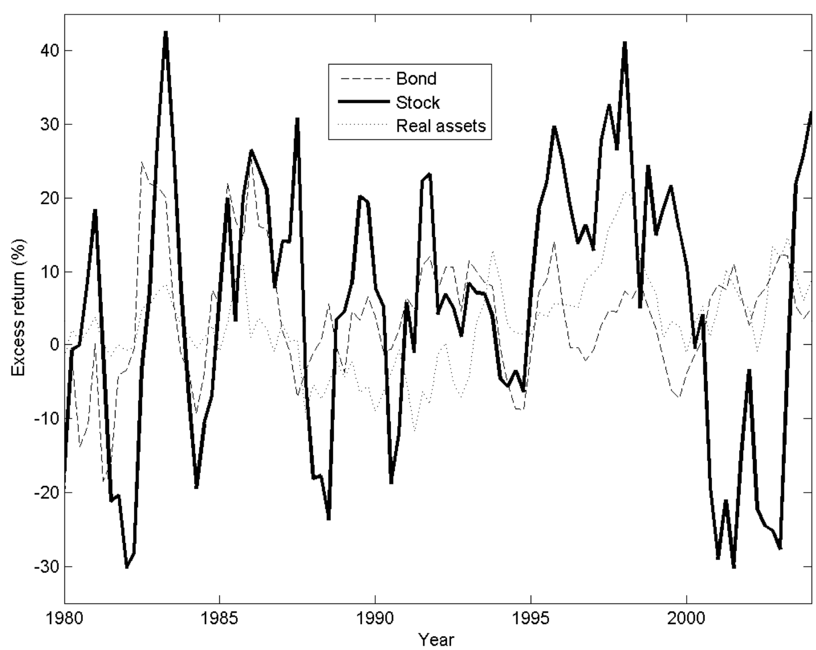


Figure 2. Historical excess returns, 1980-2004



Note: real wealth returns before 1985 are predicted values from a regression of real wealth return on bond and stock returns after 1985.

Figure 3. Risk aversion empirical cumulative distribution

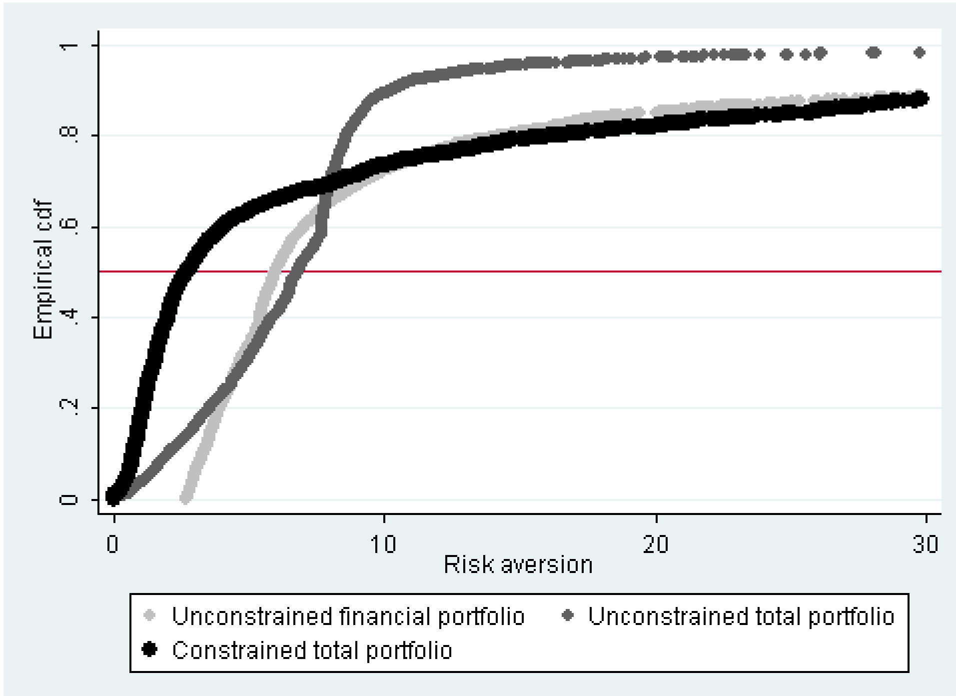


Figure 4. Optimization bias (%) empirical cumulative distribution