RISK AVERSION AND PORTFOLIO CHOICE[*]

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Abstract

We derive from a sample of US households the distribution of the relative risk aversion implicit in their portfolio choice. Our estimate minimizes in a static framework the wealth loss incurred with sub-optimal portfolio allocations; this way we also obtain a lower bound of the wealth loss. Our preferred measure accounts for real wealth and constraints in portfolio composition. Most of our estimates take plausible values. We find a substantial heterogeneity in risk aversion, and find a significant relationship with several socio-demographic characteristics. The lower bound of wealth loss is small and inversely related to risk aversion.

JEL classification codes: D81, G11.

Keywords: risk aversion; portfolio choice; real wealth; wealth loss; investment restrictions.

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1. Introduction

Economic models typically assume that individuals make their choices maximizing a utility function conditional on their preference parameters. Among these subjective parameters, the coefficient of relative risk aversion is one of the most important when uncertainty matters. In this paper we provide an estimate of this measure based on information on the portfolio allocation of US households. Our underlying assumption is that portfolio composition reflects an investor's risk aversion.

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]. Our approach is to derive a measure of risk aversion that reduces the utility loss due to investment mistakes. For each portfolio we observe, we compute an alternative portfolio that maximizes the next-period expected utility function. The comparison between this expected utility and the one with the observed portfolio is then established in terms of wealth compensative variation (or wealth loss). The compensative variation approach is commonly used in the financial literature to compare observed and optimal situations. Paiella (2007), for instance, uses this method to measure a lower bound of the cost of non-participation in financial markets. We instead use this approach to estimate the coefficient of relative risk aversion for which the compensative variation is as close as possible to zero. The compensative variation associated with this "implicit" measure of risk aversion is then a lower bound to the wealth loss due to sub-optimal allocation.

The literature finds mixed evidence on how various factors – especially wealth – impact risk aversion. We investigate this issue using the information available in the wave 2004 of the US Survey of Consumer Finances (SCF). Households typically hold most of their wealth in residential housing. The treatment of this asset in the portfolio is not trivial. Because individuals may hold residential housing for consumption as well as investment purposes, real wealth and related liabilities are often excluded from previous analyses. Yet home equity is typically the largest components of household wealth; on average it represents about two thirds of households' assets in our dataset. Similarly, mortgage debt for the primary residence is by far the largest type of liability. For this reason we consider home

[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).

ownership and mortgages in our analysis, and check the sensitivity of our findings to the exclusion of real wealth in the household portfolio.

We expect the inclusion of real wealth in the analysis to reduce the size of our estimates. Housing price markets have been very volatile in the past years. Since large shares of household wealth are held in residential housing, our approach would conclude for a generalized higher propensity to risk when the definition of wealth is extended. Yet the holding of real wealth may be driven, at least partly, by a consumption motive. Furthermore, transaction costs incurred when buying or selling real assets are so high that such portfolio positions may be seen as completely illiquid in the short run (see Grossman and Laroque, 1990). To correct for the potential bias in our estimates, we take as fixed the holding of residential housing. An optimizing agent in our problem chooses the allocation of her wealth conditional on the stock held in residential housing. While this may appear a strong assumption, we believe it is reasonable in a static framework. We expect our risk aversion estimates in this constrained case to be more comparable with those based on the financial portfolio. We complete our analysis of market imperfections allowing for inequality constraints in financial assets such as deposits, bonds, or stocks. Short-selling in financial markets is not prohibited, but discouraged by the fact that proceeds are not normally available to be invested elsewhere. This is enough to eliminate a private investor with just mildly negative beliefs (Figlewski, 1981).

We estimate risk aversion for a representative agent and separately for each household in our sample. 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. 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. Our findings may also be of interest to financial advisors, who may use our results to design products suited to investors' preferences. Since in our framework risk aversion and portfolio composition are intimately related, estimates of the risk aversion inferred from household characteristics may give an indication of the preferred allocation.

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, that is based on Bucciol and Miniaci (2007). Section 4 describes our survey data (SCF) and time series data (covering monthly the years 1975-2004). Section 5 reports our estimates of the coefficient of relative risk aversion. We first provide a value for a representative agent and then the distribution of the coefficient computed separately from each observation in our sample. Section 6 shows our estimates of the wealth loss lower bound, computed the same way. Finally, Section 6 concludes.

2. Previous estimates of the coefficient of relative risk aversion

For a concave utility function $u(\cdot)$ defined over wealth W, Pratt (1964) and Arrow (1965) independently suggested the elasticity of marginal utility with respect to wealth, or $\gamma = -W\,u''(W)/u'(W)$, as an appropriate measure of relative risk aversion. Subsequent empirical research has addressed the size of γ and its relationship with economic and, more recently, socio-demographic variables.

The size of the coefficient of relative risk aversion is still an empirical issue. Its estimate varies with the data and the specific environment studied. Most early analyses are based on aggregate data. Farber (1978) estimates preferences of workers from collective bargaining agreements and obtains results consistent with a γ of at least 2.5. Consumption-based estimates 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 γ between 1.6 and 5.3 from a structural model of equity pricing.

The availability of good-quality survey datasets allowed to estimate the heterogeneity of risk aversion in microdata. An early contribution is Friend and Blume (1975). Studying the demand for risky assets in the precursor of the current US Survey of Consumer Finances (SCF), the authors conclude that in most cases γ is greater than 2. More recently, Shaw (1996) finds a negative link between risk aversion and human capital investment from SCF data on risky financial decisions. Halek and Eisenhauer (2001) estimate the coefficient of relative risk aversion from US Health and Retirement Study (HRS) data on life insurance purchases, obtaining a mean of 3.7 and a median of 0.9. Some authors estimate the coefficient of relative risk aversion from hypothetical survey questions, asking to compare different lotteries. Barsky et al. (1997) use HRS data and find substantial heterogeneity across individuals. Similar analyses are performed in Donkers and van Soest (1999) 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).

Research into the impact of income and wealth seems to support a negative relationship with risk aversion (Friedman, 1974; Cohn et al., 1975; Riley and Chow, 1992; Shaw, 1996), at least until a large threshold. Friend and Blume (1975) also find evidence of a negative relationship, but only when owner-occupied housing is not included in the definition of wealth. Siegel and Hoban (1982) find patterns consistent with decreasing or constant relative 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. Estimates in Halek and Eisenhauer (2001) account for human capital and suggest that risk aversion follows a parabolic trend in wealth, increasing over a wide range but decreasing after a large threshold.

A more recent strand of literature investigates the link between risk aversion and some household socio-demographic characteristics. In general, there seems to be agreement in the literature 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. The most important is probably age. Financial advisors suggest to reduce the holding of risky assets with age. This recommendation may be the result of a shorter planning horizon length or a higher exposure to health shocks of the elderly, and can be described with an increase in risk aversion. While the majority of the empirical studies have found that risk aversion indeed increases 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. The financial literature, furthermore, suggests that investors should *not* reduce their holdings of risky assets with age (Cocco et al., 2005; Gomes and Michaelides, 2005). This result is however generally driven by the assumption of constant relative risk aversion (CRRA) period utility functions. Mixed results are also obtained with regards to marital status. A number of studies have failed to identify any significant relationship (McInish, 1982). Contradictory evidence also emerges from the relationship between risk aversion and race. Riley and Chow (1992), for instance, observe that whites exhibit lower risk aversion, while Halek and Eisenhauer (2001) obtain higher risk aversion.

This brief survey suggests that there is little consensus in the literature on the size of relative risk aversion, its link with wealth, or its differences across demographic groups. With our approach we aim to shed new light on these open issues.

3. The model

An investor's preferences at time t are described by the expected value of a power utility function defined over wealth at the end of the following period $t+1$, W_{t+1}:

$$U\left(W_{t+1}\right)=\frac{W_{t+1}^{1-\gamma}-1}{1-\gamma}$$

where $\gamma>0$ is the coefficient of relative risk aversion (RRA). Without loss of generality, the endowment is given by one risk free asset (with return r_0) and a set of n risky assets (with vector of expected returns η and covariance matrix Σ). The agent holds a portfolio of weights $\omega=\left[\omega_1 \quad \omega_2 \quad \dots \quad \omega_n\right]'$. Assuming that the price of the assets follows a geometric Brownian motion, the expected utility function associated with this investment is given by (see Bucciol and Miniaci, 2007, for details)

$$(1) \qquad E\left[U\left(W_{t+1}\right)\mid \omega,\gamma,W_t\right]=\frac{1}{1-\gamma}\left(W_t^{1-\gamma}\exp\left\{(1-\gamma)\left(\omega'\eta+r_0-\frac{1}{2}\gamma\omega'\Sigma\omega\right)\right\}-1\right)$$

3.1. Efficiency metric

Our measure of wealth compensative variation arises from the comparison between the expected utility function in (1) and the expected utility associated with the optimal portfolio of weights $w^*=\left[w_1^* \quad w_2^* \quad \dots \quad w_n^*\right]'$ that solve the problem

$$\max_w E\left[U\left(W_{t+1}\right)\mid w,\gamma,W_t\right]$$

subject to equality and inequality constraints on its composition:

(2) $$Aw = a$$

(3) $$lb \leq w \leq ub$$

In the absence of constraints the optimal portfolio weights are given by

(4) $$w^*(\gamma) = \frac{1}{\gamma} S^{-1} e$$

as in the mean-variance framework. The equivalence between expected utility and mean-variance frameworks, in the absence of constraints, is guaranteed by the two assumptions of i) preferences described by power utility functions with risk aversion γ and ii) prices following geometric Brownian motions.

We determine the level of initial wealth $W_t^* = W_t(1-\rho(\gamma))$ that is needed to obtain with the optimal portfolio the same expected utility as with the observed portfolio and initial wealth W_t:

$$E\left[U(W_{t+1}) \mid w^*(\gamma), \gamma, W_t(1-\rho(\gamma))\right] = E\left[U(W_{t+1}) \mid \omega, \gamma, W_t\right]$$

Solving for the *wealth compensative variation* $\rho(\gamma)$,

(5) $$\rho(\gamma) = \left[1 - \exp\left\{\left(\omega'\eta - \frac{1}{2}\gamma\omega'\Sigma\omega\right) - \left(w^*(\gamma)'\eta - \frac{1}{2}\gamma w^*(\gamma)'\Sigma w^*(\gamma)\right)\right\}\right]$$

This function measures the fraction of initial wealth that an agent wastes over the period $[t, t+1]$, when investing in the portfolio ω instead of the optimal alternative $w^*(\gamma)$. In general $\rho(\gamma) \in (-\infty, 1]$, but $\rho(\gamma) \in [0,1]$ if the observed portfolio ω is consistent with the constraints imposed to the optimal portfolio $w^*(\gamma)$. In this case (that we will assume hereafter) the two portfolios are derived from the *same* space of primitive assets, and the portfolio ω cannot be more efficient than the portfolio $w^*(\gamma)$, i.e., $\rho(\gamma) \geq 0$. If $\rho(\gamma) = 0$, the agent is investing in an efficient portfolio that does not waste any wealth. If $\rho(\gamma) = 1$, the investment is completely inefficient and the agent is wasting 100 percent of her wealth between periods t and $t+1$.

It is useful to consider a monotonic transformation of equation (5), the *utility loss* $\lambda(\gamma)$:

$$\begin{aligned} \lambda(\gamma) &= -\log(1-\rho(\gamma)) = \\ &= \left(w^*(\gamma)'\eta - \frac{1}{2}\gamma w^*(\gamma)'\Sigma w^*(\gamma)\right) - \left(\omega'\eta - \frac{1}{2}\gamma\omega'\Sigma\omega\right) \end{aligned}$$

Its sample counterpart is

$$l(\gamma) = \max_{w} \left\{ \left(w'e - \frac{1}{2}\gamma w' S w \right) - \left(\omega' e - \frac{1}{2}\gamma \omega' S \omega \right) \right\}$$

that may be subject to the constraints (2) and (3), where (e, S) consistently estimate the true asset moments (η, Σ) from a time series of length T,

$$e = \frac{1}{T}\sum_{t=1}^{T} e_t = \frac{1}{T}\sum_{t=1}^{T} \begin{bmatrix} e_{1t} \\ \vdots \\ e_{nt} \end{bmatrix}; \qquad\qquad S = \frac{1}{T}\sum_{t=1}^{T} e_t e_t' - ee'$$

Randomness in $l(\gamma)$ is given only by the first and second moments of the returns to the primitive assets. Requiring some mild assumptions, Bucciol and Miniaci (2007) derive an asymptotic normal distribution for $l(\gamma)$. For standard time series lengths, however, they suggest to use a block-bootstrap simulated distribution of the statistic.

3.2. Implicit risk aversion

We estimate γ by choosing the value that leads to the lowest utility loss. We solve the problem

$$\hat{\gamma} = \arg\min_{\gamma} \max_{w} \left\{ \left(w'e - \frac{1}{2}\gamma w' S w \right) - \left(\omega' e - \frac{1}{2}\gamma \omega' S \omega \right) \right\}$$

that may be subject to constraints (2) and (3).

If there are no restrictions, optimal portfolio weights are given by equation (4) and we estimate γ as

$$\hat{\gamma} = \arg\min_{\gamma} \left\{ \frac{1}{2\gamma} e' S^{-1} e + \frac{1}{2}\gamma \omega' S \omega - \omega' e \right\}$$

It turns out that

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

In this case it is possible to derive a standard error and a confidence interval for $\hat{\gamma}_0$. A similar, though more complex, closed-form solution is available in the presence of only equality constraints (2) (see Bucciol and Miniaci, 2007). When inequality constraints (3) are also present, a closed-form solution is not available, and the optimal risk aversion $\hat{\gamma}_1$ is implicitly defined in the equation

$$\omega' S \omega = w^*\left(\hat{\gamma}_1\right)' S w^*\left(\hat{\gamma}_1\right) \tag{7}$$

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 focus on wealth-related information imposes special requirements on the sample design for the survey. One problem is that several attributes are highly concentrated in a relatively small part of the population. To address this issue the SCF oversamples relatively wealthy households. Weights are provided to give a measure of the frequency with which households similar to the sample households could be found in the population. A second problem with wealth-related microdata is the high rate of non-response. The SCF handles missing data computing 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 drop from our dataset the few households with negative wealth, and neglect from the analysis 299 household (7.32 percent of the sample) whose portfolio contains only deposits; such households are infinitely risk averse in our framework. Our final sample consists of 3,781 observations on household socio-demographic and economic characteristics.

Table 1. Portfolio composition

Category	Constraint	Aggregate share in SCF	
		Financial	Financial + Real
Deposits	(≥ 0)		
Checking accounts		0.0555	0.0272
Savings and money market accounts		0.0854	0.0417
Call accounts at brokerages		0.0126	0.0060
IRA-KEOGH accounts		0.0218	0.0105
Retirement accounts		0.0079	0.0038
Annuities		0.0087	0.0044
Trust-managed accounts		0.0119	0.0059
TOTAL		**0.2039**	**0.0992**
Government bonds			
Certificates of deposits		0.0443	0.0212
Savings bonds		0.0064	0.0031
Tax free mutual funds		0.0171	0.0081
Govt. bond mutual funds		0.0054	0.0026
Life insurances (cash value)		0.0345	0.0165
Credit card balances (-)		-0.0104	-0.0073
Mortgages on primary residence (-)		-	-0.1473
Lines of credit on primary residence (-)		-	-0.0045
Loans on other real wealth (-)		-	-0.0379
TOTAL		**0.0973**	**-0.1456**
Corporate bonds	(≥ 0)		
Corp. bonds		0.0650	0.0309
Other bond mutual funds		0.0104	0.0050
½ Balanced mutual funds		0.0065	0.0031
½ Other mutual funds		0.0060	0.0028
IRA-KEOGH accounts		0.0577	0.0275
Retirement accounts		0.0078	0.0037
Annuities		0.0086	0.0041
Trust-managed accounts		0.0189	0.0090
TOTAL		**0.1808**	**0.0861**
Stocks	(≥ 0)		
Directly held stocks		0.2106	0.1001
Stock mutual funds		0.1181	0.0561
½ Balanced mutual funds		0.0065	0.0031
½ Other mutual funds		0.0060	0.0028
IRA-KEOGH accounts		0.1124	0.0535
Retirement accounts		0.0189	0.0091
Annuities		0.0128	0.0061
Trust-managed accounts		0.0327	0.0156
TOTAL		**0.5180**	**0.2465**
Real wealth	($\geq$ *Primary residence*)		
Primary residence		-	0.5227
Other real wealth		-	0.1911
IRA-KEOGH accounts		-	0
Retirement accounts		-	0
Annuities		-	0
Trust-managed accounts		-	0
TOTAL		**-**	**0.7138**

Note: Estimates exclude risk-free portfolios. Number of observations: 3,255 for financial portfolios and 3,781 for financial and real portfolios. Aggregate shares account for multiple imputations and sampling weights.

Our broader definition of wealth includes real estate and other properties owned by a business. We aggregate the available information on asset holdings in five categories: deposits, government bonds, corporate bonds, stocks, and real wealth. Table 1 shows the composition of each category. The SCF is exceptionally good in giving detailed information on composite assets. With regards to mutual funds, we know whether they are tax-free, government bond, corporate bond, balanced, stock or other funds and group them accordingly. We arbitrarily assume that balanced and other funds are equally divided in corporate 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"), corporate bond (if in "annuities or other assets"), stocks (if in "stocks", "hedge funds", or "mineral rights"), or real wealth (if in "real estate"). 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 remains to corporate bonds.

Our narrower definition of wealth considers only financial assets. Portfolio holdings are grouped in four categories: deposits, government bonds, corporate bonds, and stocks. Few households do not own deposits in any form. We disregard from government bonds those liabilities (mortgages, lines of credit) that are directly related to real wealth. After excluding observations with risk-free portfolios, we are left with 3,255 observations. Note that we exclude more risk free portfolios when we focus on financial wealth, as many households in our sample (526, 12.88 percent) hold only deposits and residential housing.

Table 1 reports the aggregate portfolio in our dataset, computed accounting for multiple imputations and sampling weights. From the table we observe that most financial wealth is held in stocks. Considering the most general wealth definition, the largest share of wealth (71.38 percent) is held in real wealth. In this case the inclusion of mortgages in the analysis determines a heavily short position in government bonds. The investment in corporate bonds is instead negligible.

Finally, it is worth noting that the size and the empirical distribution of household wealth changes markedly using either definition. When real assets are included in the definition, wealth is markedly larger (Figure 1). While we find a median wealth of 86,270 USD using our broader definition, the median is only 27,864 USD using the narrower definition of financial wealth (Table 2).

Figure 1. Empirical cumulative distribution function of household wealth

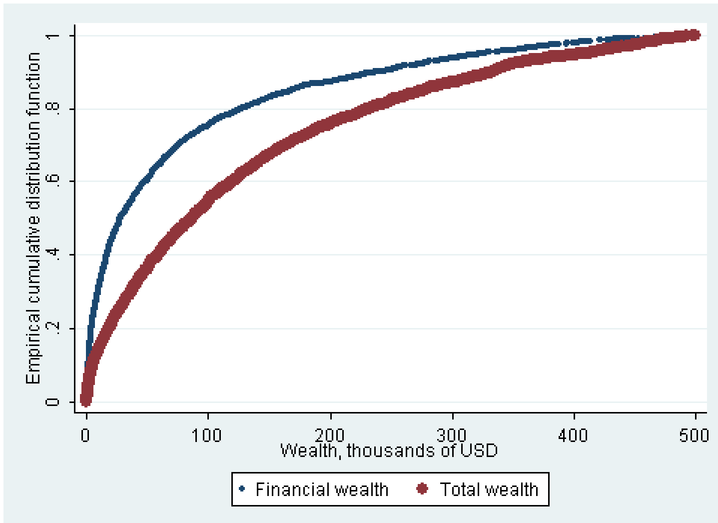


Table 2. Percentiles of empirical wealth distribution (thousands of dollars)

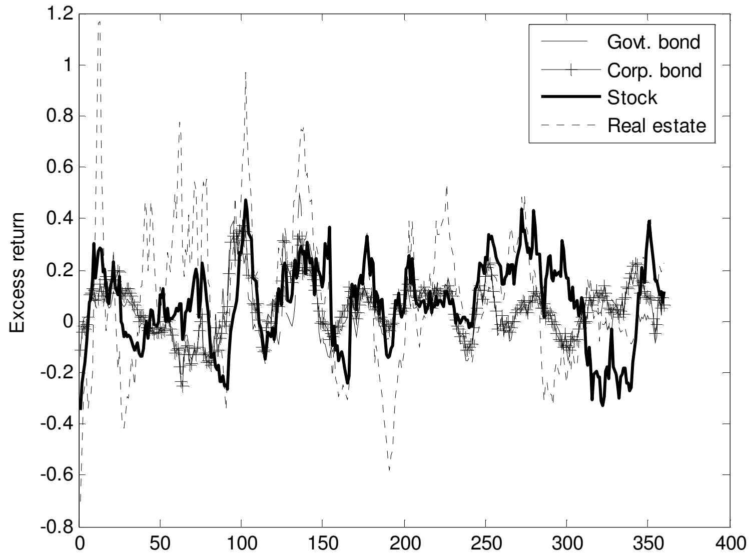
Wealth definition	Percentile				
	10th	**25th**	**50th**	**75th**	**90th**
Financial	1.5000	6.3202	27.8640	98.0000	236.9000
Financial and real	4.9800	26.8000	86.2700	192.1000	332.7000

Note: The estimates accounts for multiple imputations and sampling weights.

4.2. Time series

We collect from Datastream time series of US asset price indices. Our series of prices are 3-month Treasury bill yields for deposits, Lehman long-term government bond index for government bonds, Lehman long-term corporate bond index for corporate bonds, MSCI stock price index for stocks, and Datastream real estate price index for real wealth. Our series of yearly returns arise from these series and are adjusted with series of return yields for government bond, corporate bond, and dividend yields for stocks. This way we take account of both capital gain and return yields, that would otherwise cancel out when we compute yearly returns from the price indices. The series are 20-year Treasury bill yields adjusted to constant maturity for government bonds, Moody's BAA corporate bond yields for corporate bonds, and S&P500 dividend yields for stocks. The first two series are taken from Datastream, and the last one from Freelunch (www.freelunch.com).

Figure 2. Historical excess returns, 1975-2004



Our final series cover the period January 1975 – December 2004 (360 observations) in a monthly frequency, and their trend is shown in Figure 2. The historical average excess return to deposits is fixed at 2.1497 percent; we consider them as risk free assets. Average returns, standard deviations and Sharpe ratios of the remaining assets are reported in Table 3. Covariances and correlations are shown in Table 4. Real wealth is by far the riskier category; also note that government bonds are dominated in a mean-variance sense by corporate bonds. For this reason tangency portfolios in an unconstrained mean-variance framework have a negative weight on this aggregate. Compared with the aggregate portfolio from SCF, weights are much lower for real wealth and much higher for corporate bonds.

Table 3. Time series statistics

Category	Excess return	Std dev	Sharpe ratio (%)	Tangency portfolio	
				Financial	Financial + real
Government bonds	0.0355	0.1076	32.9618	-0.6991	-0.7420
Corporate bonds	0.0531	0.1068	49.7073	1.3518	1.3753
Stocks	0.0704	0.1641	42.8874	0.3472	0.2868
Real wealth	0.0968	0.2780	34.8368	-	0.0798

Table 4. Covariance and correlation (in italic)

Category	Government bonds	Corporate bonds	Stocks	Real wealth
Government bonds	1.1575	*0.8721*	*0.2179*	*0.2653*
Corporate bonds	1.0017	1.1397	*0.2875*	*0.2849*
Stocks	0.3847	0.5034	2.6912	*0.5351*
Real wealth	0.7933	0.8453	2.4403	7.7273

5. The relative risk aversion implicit in households' portfolio choice

We believe that households consider all their wealth (financial and real) when they choose how to allocate it. The risk aversion implicit in their choice is thus better captured from observed portfolios including real wealth. Yet dealing with real wealth is problematic as the holding of residential housing may be driven by a consumption rather than investment motive. 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. We instead choose to account for constraints in portfolio composition, in particular on real wealth. In our static framework we assume that households choose the allocation of wealth *conditional* on their holding $\overline{w}$ of primary residence. Disregarding non-negativity constraints, this implies that optimal weights in the portfolio allocation problem are given by

$$w^* = \frac{1}{\gamma} S^{-1} e - S^{-1} C \overline{w} \tag{8}$$

with C covariance between the returns of unconstrained and constrained assets. Compare equation (8) with (4). Optimal portfolio allocation accounts for a 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 compare estimates of RRA where the role of constraints in the composition of financial and real portfolios is acknowledged, with estimates where constraints are not considered in the composition of financial portfolios, or financial and real portfolios.

5.1. Risk aversion of a representative agent

We first present a measure of relative risk aversion for a representative agent in our sample. The estimates we show in Table 5 are computed in two alternative ways. In the most general case we derive the implicit risk aversion γ from a characterization of equation (7) based on i) the aggregate portfolio of weights $\overline{\varpi}$,

$$\overline{\varpi}' S \overline{\varpi} = w^*(\gamma)' S w^*(\gamma)$$

and ii) the average portfolio variance $\overline{\varpi' S \varpi}$,

$$\overline{\varpi' S \varpi} = w^*(\gamma)' S w^*(\gamma)$$

In the former case we are able to associate a lower bound to the wealth loss with respect to the aggregate portfolio,

$$\left(w^*(\gamma)' e - \frac{1}{2}\gamma w^*(\gamma)' S w^*(\gamma) \right) - \left(\bar{\omega}' e - \frac{1}{2}\Gamma \bar{\omega}' S \bar{\omega} \right)$$

We compute aggregate portfolio weights and average portfolio variance in our sample, controlling for sampling weights and imputations. Using the approach based on the aggregate portfolio, we estimate a relative risk aversion of around 6.30 from the financial wealth, and a relative risk aversion of 2.79 and 2.29 from the unconstrained and constrained total portfolio respectively. Our measure of risk aversion reduces when we consider real wealth, the riskiest asset in our endowment. Real assets account for a large part of household wealth (about 71 percent, see Table 1), and our measure is even lower when we keep the value of the primary residence (52 percent of total wealth) as fixed. Using the approach based on the average portfolio variance, our estimates are lower. We compute a relative risk aversion of 0.62, 0.89, and 0.54 in the three cases. Estimates now increase when we incorporate real wealth in the analysis, because household portfolios are more highly diversified and produce a slightly lower average variance.

Table 5. Aggregate estimates

	Financial wealth	Financial + real wealth	
	Unconstrained		Constrained
RRA	6.3040	2.7921	2.2931
from aggregate portfolio	(0.1065)	(0.0381)	(0.0043)
RRA	0.6159	0.8929	0.5452
from aggregate utility loss	(0.0400)	(0.0942)	(0.0106)
% wealth loss	0.9640	4.9662	3.1766
from aggregate portfolio	(0.0404)	(0.1138)	(0.0502)

Note: Standard errors in parentheses are based on 1,000 bootstrap simulations. The estimates accounts for multiple imputations and sampling weights.

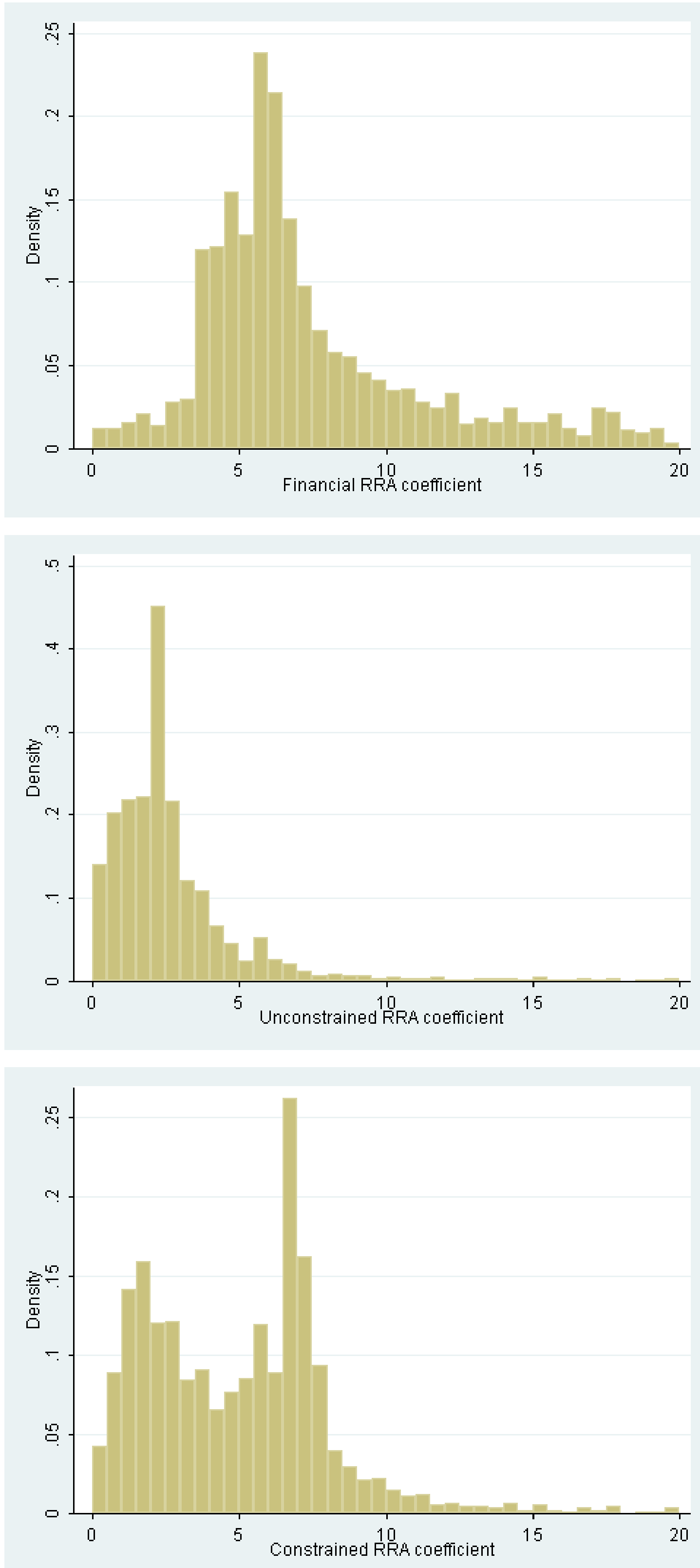
The wealth loss associated with the aggregate portfolio exhibits a negligible lower bound of 0.96 percent per year with the financial portfolio, and lower bounds of 4.97 and 3.18 percent with the unconstrained and constrained financial and real portfolios. The three measures are not directly comparable as they refer to different levels of wealth. While we find that the financial wealth wasted investing in the aggregate rather than the optimal portfolio is no lower than 0.96 percent in a year, the estimates 4.97 and 3.18 refer to the loss in financial *and* real wealth, which in general is much larger (see Table 2).

The measures we report in Table 5 are accompanied by a bootstrap standard error. We keep the time series returns fixed and resample 1,000 times our household observations, stratifying by wealth quintiles. Every time we generate a dataset including five imputations of 4,000 portfolio observations, from which we estimate the relative risk aversion and wealth loss. Our standard errors are the estimated standard deviations of these measures. In each case we consider, the bootstrap standard error is lower with the constrained rather than with the unconstrained financial and real portfolio. The standard error with respect to the relative risk aversion coefficient in this case is also markedly lower than the one we compute from the financial wealth.

5.2. Risk aversion heterogeneity

Heterogeneity may be important in subjective preferences. We investigate this issue computing a measure of implicit relative risk aversion from each household portfolio in our dataset. Figure 3 shows that risk aversion indeed varies widely within our sample, especially when we focus on financial wealth only. The measure is instead more highly concentrated when we also account for real wealth. The distribution of risk aversion in our sample is skewed; the one based on the constrained portfolio, furthermore, exhibits a concentration of values around 2 and 7.

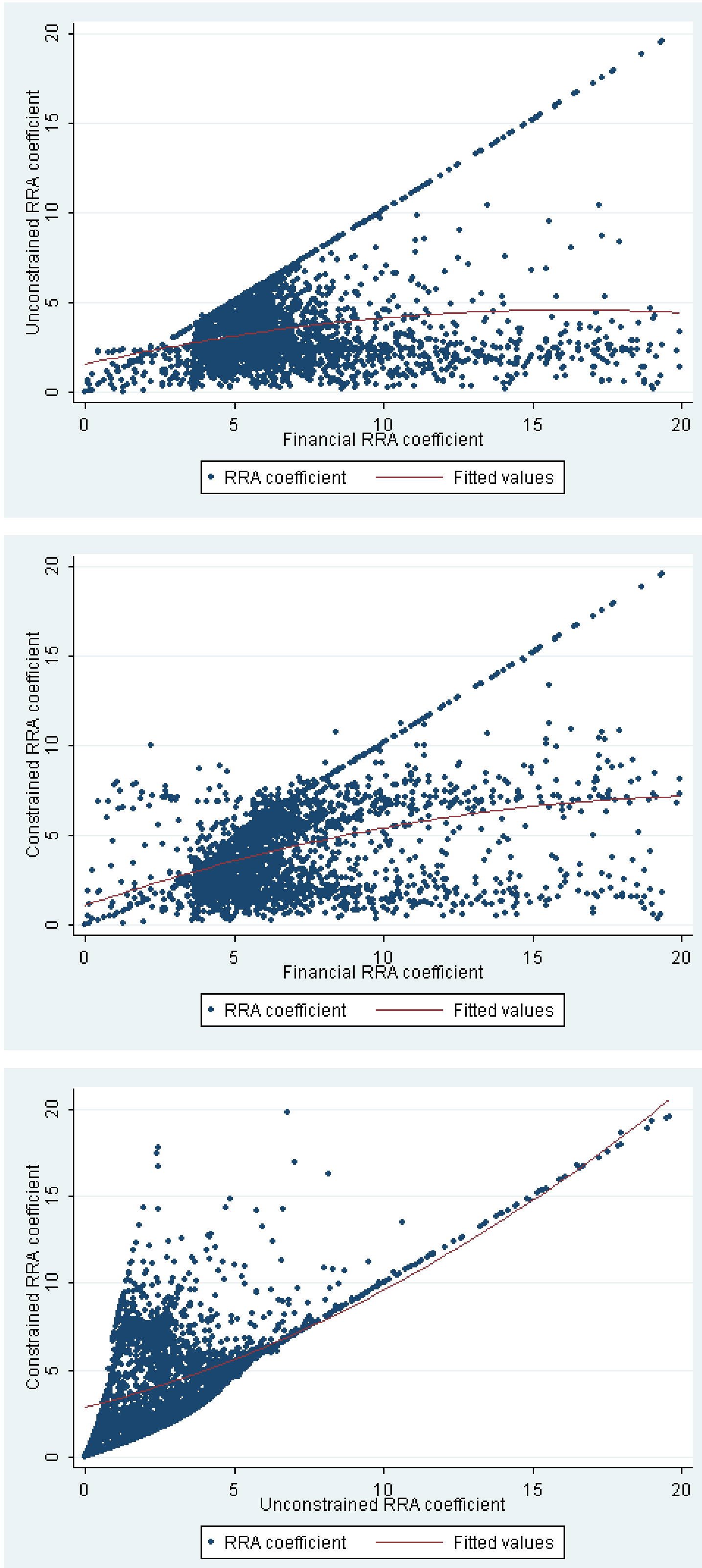
Figure 3. Implicit RRA distribution



Note: we exclude the cases of RRA >20.

Figure 4 compares our estimates of the implicit relative risk aversion derived from unconstrained financial portfolio, γ_0^F, from the unconstrained total portfolio, γ_0^{FR}, or from the constrained total portfolio, γ_1^{FR}. A pattern emerges in the relationship between our measures. The estimates γ_0^{FR} and γ_1^{FR} are in most cases lower than γ_0^F; it also seems that γ_1^{FR} is often higher than γ_0^{FR}. Table 6 informs that $\gamma_0^{FR} < \gamma_0^F$ in 3,292 cases out of 3,781 (87.07 percent of the sample), and that γ_1^{FR} is lower than γ_0^F in 3,247 cases (85.88 percent) and higher than γ_0^{FR} in 2,057 cases (54.40 percent). To understand what forces drive this behavior, the table reports the composition of the aggregate total portfolio of households for which one estimate is lower or higher than the other. From the comparison between γ_0^{FR} and γ_0^F we see that the critical parameter is the share of wealth held in real assets. Risk aversion is estimated lower when we include real wealth in the portfolio, and this risky asset represents a larger share of total wealth. From the table we also learn that γ_1^{FR}, the estimate based on the constrained total portfolio, is more likely to be higher when real wealth is held almost entirely in residential housing, i.e., when the constraint on real wealth binds or is close to bind. Imposing the constraint on real wealth, we assume that the decision to allocate wealth in residential housing is driven by consumption rather than investment motives, and rescale the space of portfolio alternatives. Our estimate of the coefficient of relative risk aversion is thus affected, among others, by the observed share of wealth held in real assets other than residential housing. When the share is small, the household is seen as highly risk averse. Consider the extreme case of a household with wealth held only in risk free assets and residential housing. In our framework, this household is infinitely risk averse looking at her financial portfolio (completely risk free). Yet the same household is much less risk averse looking at her financial and real portfolio, since a share of wealth is held in risk assets. The estimate of risk aversion increases when constraints on total portfolio composition are included in the analysis, because the household holds no real wealth other than residential housing. Risk aversion is however less than infinite because the household does not hedge against the risk associated to the constrained part of the portfolio.

Figure 4. Comparison between RRA estimates



Note: we exclude the cases of RRA >20.

Table 6. Comparison between alternative RRA estimates

	Obs.	Portfolio weights: Deposits	Govt. bonds	Corp. bonds	Stocks	Real wealth	Constraint: Primary residence
based on unconstrained financial and real wealth vs. based on financial wealth							
$\gamma_0^{FR} \leq \gamma_0^F$	3292	0.0986	-0.1526	0.0835	0.2348	0.7357	0.5381
$\gamma_0^{FR} > \gamma_0^F$	489	0.1114	0.0357	0.1597	0.5550	0.1382	0.1162
based on constrained financial and real wealth vs. based on financial wealth							
$\gamma_1^{FR} \leq \gamma_0^F$	3247	0.0992	-0.1517	0.0857	0.2549	0.7118	0.5114
$\gamma_1^{FR} > \gamma_0^F$	534	0.0958	-0.0244	0.0986	0.0912	0.7387	0.7314
based on constrained vs. unconstrained financial and real wealth							
$\gamma_1^{FR} \leq \gamma_0^{FR}$	1724	0.0736	-0.1028	0.0866	0.3192	0.6233	0.2834
$\gamma_1^{FR} > \gamma_0^{FR}$	2057	0.1295	-0.1966	0.0860	0.1604	0.8206	0.8079
Whole sample	**3781**	**0.0992**	**-0.1456**	**0.0861**	**0.2465**	**0.7138**	**0.5227**

Note: γ_0^F *is the RRA estimate based on the financial portfolio;* γ_0^{FR} *and* γ_1^{FR} *are the unconstrained and constrained RRA estimates based on the financial and real portfolio respectively. The estimates accounts for multiple imputations and sampling weights.*

We now compare our estimates with respect to several characteristics of our sample. Since our approach derives a measure of risk aversion from information on portfolio allocation, we first consider the link between risk aversion and portfolio holdings. Tables 7 and 8 report aggregate total portfolios and the 10th, 50th and 90th percentiles of risk aversion[2] in the whole sample and when households choose to make no investment in one asset, or their real wealth holdings are entirely in residential housing. Table 7 informs that almost all households have some wealth held in deposits, many own real wealth financed with a mortgage –and therefore our weight of government bonds is negative – but only 63 percent of them hold stocks either directly or indirectly, and fewer hold corporate bonds. The median relative risk aversion we estimate in our sample is 7.3083 from the financial portfolio, 2.2867 from the financial and real portfolio, and 5.3388 from the constrained financial and real portfolio; our measure varies less when we include real wealth in the portfolio (see Table 8). Note that the median values we obtain from the analysis based on unconstrained portfolios are comparable with those we found with the aggregate portfolios (6.3040 and 2.7921 respectively), while the median value based on the constrained portfolio is now more than doubled (5.3388 instead of 2.2931); aggregation of individual preferences may be more problematic with the non-linearity introduced by constraints on portfolio composition.

[2] The distribution of the risk aversion coefficient is skewed, and the average is raised by the presence of a few extremely large outliers. For this reason we pay attention to median rather than mean values.

We can find two regularities from the comparison between Tables 7 and 8. First, more highly specialized portfolios are associated to lower coefficients of risk aversion. This is intuitive as specialized portfolios are also riskier. Second, the main driver of the values we obtain is the weight on real wealth, the riskier asset in our portfolio. In particular, in the constrained case, it is the holding of other real wealth than the primary residence that matters. Table 8 also suggests that the concentration around 2 and 7 of the estimate based on the constrained portfolio (see the bottom panel of Figure 4) corresponds to the cases of unbounded (median constrained risk aversion of 1.8364) and bounded (median of 6.4338) real wealth weights.

Table 7. Aggregate portfolio by portfolio composition (SCF 2004)

		Portfolio weights					Constraint
	Obs.	**Deposits**	**Govt. bonds**	**Corp. bonds**	**Stocks**	**Real wealth**	**Primary residence**
Deposits							
= 0	121	0	-0.3120	0.0014	0.0485	1.2621	1.2005
> 0	3660	0.0996	-0.1446	0.0868	0.2480	0.7103	0.5186
Government bonds							
≤ 0	2641	0.0927	-0.3074	0.0757	0.2308	0.9082	0.6692
> 0	1140	0.1082	0.0870	0.1017	0.2701	0.4330	0.3109
Corporate bonds							
= 0	2250	0.1235	-0.2436	0	0.1439	0.9761	0.7505
> 0	1531	0.0831	-0.0812	0.1430	0.3145	0.5407	0.3724
Stocks							
= 0	1399	0.1315	-0.3104	0.0102	0	1.1687	0.9666
> 0	2382	0.0925	-0.1120	0.1018	0.2971	0.6206	0.4319
Real wealth							
= primary residence	2337	0.1172	-0.1817	0.0834	0.2480	0.7331	0.7331
> primary residence	1444	0.0835	-0.1144	0.0889	0.2461	0.6960	0.3413
Binding constraints							
At least one constraint is binding	2977	0.1144	-0.1792	0.0596	0.2205	0.7848	0.6440
No constraint is binding	804	0.0698	-0.0810	0.1375	0.2975	0.5761	0.2893
Whole sample	**3781**	**0.0992**	**-0.1456**	**0.0861**	**0.2465**	**0.7138**	**0.5227**

Note: "Primary residence" is included in the "Real wealth" share and is used as a lower bound for this weight in the constrained analysis. The estimates accounts for multiple imputations and sampling weights.

Table 8. Implicit RRA by portfolio composition

	Obs.	Financial wealth			Financial + real wealth					
		Unconstrained RRA						Constrained RRA		
		10^{th}	50^{th}	90^{th}	10^{th}	50^{th}	90^{th}	10^{th}	50^{th}	90^{th}
Deposits										
= 0	121	3.7232	5.6771	5.6771	0.6456	2.2233	5.7445	1.4321	6.4392	6.8824
> 0	3660	4.0705	7.4609	100.726	0.6736	2.3041	6.4466	1.2793	5.2258	9.6275
Government bonds										
≤ 0	2641	3.2860	7.0489	159.830	0.5490	1.9867	4.1598	1.0998	4.1999	8.4754
> 0	1140	4.9685	7.4716	66.9480	2.4023	3.7946	11.6473	2.8826	6.2654	14.2650
Corporate bonds										
= 0	2250	3.8436	9.4020	185.257	0.5723	2.9836	7.0997	1.2347	6.0826	10.8800
> 0	1531	4.4020	6.3015	16.2291	1.1195	2.8228	5.3370	1.5354	4.1601	7.1322
Stocks										
= 0	1399	5.6771	17.5552	684.973	0.5048	2.2003	10.0182	1.2965	6.7859	14.2844
> 0	2382	3.9371	6.2467	17.5430	0.9440	2.6337	5.3917	1.3223	3.8340	7.3708
Real wealth										
= primary residence	2337	-	-	-	0.6058	2.2678	7.2278	1.8241	6.4338	10.7510
> primary residence	1444	-	-	-	1.0609	2.3205	3.9718	0.8449	1.8364	4.8548
Binding constraints										
At least one	2977	3.8464	9.3484	185.257	0.6379	2.2527	6.5433	1.3689	5.7445	9.8152
No constraint	804	4.3883	6.2947	16.6020	1.3188	2.7331	4.5951	1.0102	2.3549	4.9146
Whole sample	**3781**	**4.0566**	**7.3083**	**97.9300**	**0.6762**	**2.2867**	**6.3182**	**1.3033**	**5.3388**	**9.4487**

Note: The estimates accounts for multiple imputations and sampling weights.

Tables 9 and 10 focus on the link between wealth or income quintiles and risk aversion. There is no consensus in the literature on how the coefficient should vary with wealth. The implicit risk aversion in our sample tends to decrease with wealth in our preferred case, when we base our analysis on the constrained financial and real portfolio. The same relationship appears with the measure estimated from the financial portfolio. Using the unconstrained financial and real portfolio, instead, we find a U-shaped risk aversion – wealth profile. Our findings depend on the definition of wealth we consider and are similar to Siegel and Hoban (1982). The measure also decreases with income when we consider financial wealth (γ_0^F) or constrained total wealth (γ_1^{FR}), while it seems almost constant across quintiles up to the last one when we consider total wealth without the constraints (γ_0^{FR}).

Table 9. Aggregate portfolio by wealth and income quintiles (SCF 2004)

	Obs.	Portfolio weights: Deposits	Govt. bonds	Corp. bonds	Stocks	Real wealth	Constraint: Primary residence
Wealth quintiles							
I	757	0.2182	-2.2101	0.0182	0.0931	2.8806	2.7719
II	756	0.1064	-0.6549	0.0181	0.0764	1.4540	1.3638
III	756	0.1177	-0.2078	0.0437	0.1293	0.9171	0.8055
IV	756	0.0939	-0.0657	0.0768	0.2497	0.6454	0.4543
V	756	0.0893	-0.0313	0.1352	0.3464	0.4605	0.2040
Income quintiles							
I	760	0.0943	-0.0868	0.0334	0.1161	0.8431	0.7273
II	756	0.1069	-0.1809	0.0511	0.1690	0.8539	0.7081
III	757	0.1256	-0.2153	0.0766	0.1871	0.8260	0.6597
IV	753	0.0961	-0.1758	0.0869	0.2663	0.7266	0.5083
V	755	0.0770	-0.0471	0.1374	0.3748	0.4578	0.2224
Whole sample	**3781**	**0.0992**	**-0.1456**	**0.0861**	**0.2465**	**0.7138**	**0.5227**

Note: "Primary residence" is included in the "Real wealthe" share and is used as a lower bound for this weight in the constrained analysis. The estimates accounts for multiple imputations and sampling weights.

Table 10. Implicit RRA by wealth and income quintiles

	Obs.	Financial wealth			Financial + real wealth					
		Unconstrained RRA						Constrained RRA		
		10th	50th	90th	10th	50th	90th	10th	50th	90th
Wealth quintiles										
I	757	2.6863	9.6297	114.472	0.5801	2.2233	35.9990	0.7835	5.7445	35.9990
II	756	4.4513	9.3998	178.830	0.7863	1.8294	3.1762	1.5386	6.5058	8.2998
III	756	4.3726	6.7047	66.7116	1.4026	2.4235	4.2334	1.6232	5.4701	8.2038
IV	756	4.2120	5.8416	13.4130	1.9336	3.0353	4.9341	1.4640	3.6102	6.8285
V	756	3.9988	5.8075	10.9470	2.2317	3.7000	5.7487	1.4848	3.0150	6.1512
income quintiles										
I	760	4.1915	8.4971	237.630	0.8136	2.3741	14.1964	1.6095	6.7463	17.8268
II	756	3.9228	8.0928	114.329	0.5023	2.2485	5.8830	1.1601	5.3341	9.3962
III	757	3.9831	7.0623	56.7710	0.6349	2.1563	4.8913	1.1772	4.2658	8.6693
IV	753	4.0303	6.2346	37.6920	0.9870	2.2614	4.2334	1.2289	3.0990	7.2784
V	755	3.9466	5.9150	10.4508	1.7640	3.1568	4.9793	1.3471	2.6571	5.7487
Whole sample	**3781**	**4.0566**	**7.3083**	**97.9300**	**0.6762**	**2.2867**	**6.3182**	**1.3033**	**5.3388**	**9.4487**

Note: The estimates accounts for multiple imputations and sampling weights.

Tables 11 and 12 show the aggregate portfolio and implicit risk aversion percentiles in our sample by household's socio-demographic characteristics. Focusing on median values, we find our estimate of the relative risk aversion to be higher for females, households whose head is not married, or households whose head reports a self-assessed fair or poor health status (Table 12). These results arise in all the three analyses we perform. Using financial wealth only, we also observe that risk aversion is higher in smaller households, for non-whites, for less educated household heads, and for those who report to make no investment. Intuitively, households who report to make no investment hold more conservative portfolios and are interpreted as more risk averse with our approach. In some cases the inclusion of real wealth in the portfolio inverts these relationships. The analysis based on constrained portfolios, however, leads back to conclusions similar to the ones we draw with financial portfolios. We indeed find the constrained risk aversion to be higher for non-whites, less highly educated individuals, and for those who report to make no investment. The analysis based on constrained portfolios also suggests that the coefficient of risk aversion is higher in smaller households, or when the head is not working (unemployed or retiree). Overall, we believe that the relationships obtained with constrained portfolios are more convincing. For instance, smaller households may have a lower capacity to share risk and are therefore likely to be more risk averse. The existing literature also agrees on the hypothesis of higher risk aversion for less highly educated households. The pattern with respect to age is not trivial. Measures based on financial portfolio or constrained financial and real portfolio exhibit a U-shaped age profile, though risk aversion is higher for young individuals in one case and for elderly ones in the other. In contrast, the measure based on unconstrained portfolio shows an increasing age profile.

Table 11. Aggregate portfolio by households' characteristics (SCF 2004)

		Portfolio weights					Constraint
	Obs.	Deposits	Govt. bonds	Corp. bonds	Stocks	Real wealth	Primary residence
Number of household members							
1	720	0.1246	-0.0693	0.0803	0.2164	0.6481	0.4852
2	1498	0.0928	-0.0798	0.1026	0.2802	0.6042	0.4194
More than 2	1563	0.0943	-0.2778	0.0668	0.2167	0.9000	0.6853
Head age							
<36	522	0.1399	-0.8953	0.0320	0.1290	1.5945	1.3281
36-50	1197	0.1025	-0.3247	0.0462	0.2206	0.9554	0.7211
51-65	1283	0.0845	-0.0922	0.0994	0.2743	0.6340	0.4474
66-80	636	0.0992	0.0066	0.1197	0.2670	0.5074	0.3405
>80	139	0.1482	0.0760	0.0650	0.1794	0.5313	0.4261
Head gender							
Male	3125	0.0980	-0.1513	0.0870	0.2562	0.7101	0.5106
Female	656	0.1061	-0.1058	0.0820	0.1839	0.7338	0.6001
Head marital status							
Not married	1091	0.1205	-0.1136	0.0733	0.2016	0.7182	0.5460
Married	2690	0.0928	-0.1548	0.0902	0.2602	0.7116	0.5151
Head race							
White	3136	0.1011	-0.1242	0.0912	0.2617	0.6702	0.4897
Non-white	496	0.0736	-0.3564	0.0385	0.0740	1.1703	0.9104
Head education							
High school or below	1322	0.1109	-0.1451	0.0471	0.1259	0.8612	0.6877
College or above	2459	0.0956	-0.1456	0.0977	0.2820	0.6702	0.4742
Head employment status							
Not worker	869	0.1124	0.0018	0.1003	0.2713	0.5142	0.3941
Employee	1827	0.0982	-0.2963	0.0667	0.2341	0.8974	0.7263
Self-employed	1112	0.0847	-0.1198	0.0954	0.2346	0.7050	0.4022
Head primary job position							
Entrepreneur	1696	0.0952	-0.1839	0.0889	0.2547	0.7451	0.5167
Professional	662	0.0839	-0.2733	0.0703	0.2134	0.9058	0.6614
Blue collar	575	0.0889	-0.3748	0.0291	0.1359	1.1209	0.9321
Head kind of business-industry							
Agriculture or mining	358	0.0972	-0.3194	0.0443	0.1191	1.0589	0.7726
Manufacturing	400	0.0926	-0.2007	0.0774	0.2582	0.7725	0.6024
Trade	401	0.0919	-0.2031	0.0742	0.1990	0.8380	0.6096
Finance	480	0.0892	-0.1751	0.0967	0.2465	0.7426	0.3989
Services or p.a.	1290	0.0932	-0.2359	0.0787	0.2555	0.8085	0.6334
Investment advisor							
Media	801	0.0944	-0.1518	0.0912	0.2886	0.6775	0.4955
Professional advisor	1231	0.0936	-0.1161	0.1044	0.2763	0.6418	0.4780
Non-professional advisor	1288	0.1022	-0.1771	0.0692	0.2062	0.7996	0.5743
No investment	704	0.0811	-0.2286	0.0383	0.1468	0.9623	0.8232
Head self-assessed health status							
Excellent or good	3129	0.0994	-0.1539	0.0886	0.2574	0.7085	0.5166
Fair or poor	648	0.0985	-0.0906	0.0656	0.1747	0.7518	0.5639
Head expectations about the future							
Better or about the same	3183	0.0976	-0.1440	0.0878	0.2558	0.7028	0.5145
Worse	557	0.1075	-0.1546	0.0777	0.1928	0.7765	0.5659
Whole sample	**3781**	**0.0992**	**-0.1456**	**0.0861**	**0.2465**	**0.7138**	**0.5227**

Note: "Primary residence" is included in the "Real wealth" share and is used as a lower bound for this weight in the constrained analysis. The estimates accounts for multiple imputations and sampling weights.

Table 12. Implicit RRA by households' characteristics

	Obs.	Financial wealth			Financial + real wealth					
		Unconstrained RRA						Constrained RRA		
		10th	50th	90th	10th	50th	90th	10th	50th	90th
Number of household members										
1	720	4.2790	7.4028	167.985	0.9082	2.6285	9.8047	1.4483	6.2536	14.2952
2	1498	4.1797	7.0108	77.4520	0.8972	2.4496	5.7445	1.4438	5.3036	8.7605
More than 2	1563	3.7847	7.5153	84.8270	0.5313	1.9267	4.9574	1.1312	4.4730	8.6812
Head age										
<36	522	4.0320	9.7342	165.624	0.3598	1.7415	28.2310	0.8465	4.5729	28.2310
36-50	1197	3.7847	7.1413	58.6630	0.6011	1.8817	4.6070	1.1643	4.2658	8.2837
51-65	1283	3.9945	6.5673	60.5560	1.0744	2.4235	4.7271	1.4562	4.9629	7.8874
66-80	636	4.6005	7.3663	160.900	1.7244	2.7259	5.7288	1.8848	6.4128	8.8721
>80	139	4.4380	8.6300	293.320	2.2233	3.0495	6.7895	3.6147	6.8261	12.6530
Head gender										
Male	3125	3.9670	7.1499	77.0710	0.6823	2.2497	5.7445	1.2347	4.8758	8.8283
Female	656	4.4443	7.8454	167.985	0.6644	2.4071	10.4254	1.5261	6.2836	14.1386
Head marital status										
Not married	1091	4.1590	7.9679	165.624	0.6594	2.4071	10.5160	1.4385	6.2263	14.1984
Married	2690	3.9808	7.0913	75.9310	0.6895	2.2274	4.7271	1.2428	4.5709	8.4189
Head race										
White	3136	4.0719	7.0859	79.4790	0.6978	2.3604	6.0327	1.3345	5.2274	9.4205
Non-white	496	3.9120	8.9958	178.830	0.5416	2.1806	6.8032	1.1976	5.9110	9.1913
Head education										
High school or below	1322	4.0566	8.1841	154.451	0.6762	2.2456	6.4385	1.4385	6.5196	9.6676
College or above	2459	4.0303	6.8993	70.9266	0.6663	2.3335	6.2701	1.1881	4.0714	9,0694
Head employment status										
Not worker	869	4.4995	7.2454	145.807	1.4161	2.7238	6.3458	1.8803	6.3830	9.6295
Employee	1827	3.9033	7.4004	92.7762	0.5058	2.0558	6.5282	1.1086	4.4968	9.4205
Self-employed	1112	3.9062	6.9219	66.2318	0.9777	2.3281	4.9328	1.2691	3.8334	8.2038
Head primary job position										
Entrepreneur	1696	3.8814	6.8303	62.9642	0.6520	2.1905	5.6905	1.0935	3.5757	8.7866
Professional	662	4.0124	7.7572	104.700	0.5267	2.2242	8.6528	1.2606	5.4706	11.5936
Blue collar	575	3.8002	8.3472	129.410	0.5034	2.0235	4.7755	1.1332	5.1057	8-6090
Head kind of business-industry										
Agriculture or mining	358	3.7894	8.1542	108.630	0.5048	1.9988	4.4740	1.1217	5.3103	8.2827
Manufacturing	400	3.8224	6.8552	101.350	0.5203	2.1792	4.6476	1.1730	3.9036	8.6090
Trade	401	3.8528	7.1042	75.2210	0.8138	2.2951	10.4910	1.4156	5.3096	13.2602
Finance	480	4.1144	6.7139	42.9840	0.6372	2.2077	6.9829	1.0205	3.7123	10.2648
Services or p.a.	1290	3.9121	7.5306	84.9014	0.5508	2.0682	6.3242	1.0930	4.0047	9.2805
Investment advisor										
Media	801	4.0320	6.8582	63.6890	0.5690	2.2946	6.7895	1.1603	4.1973	9.9000
Professional advisor	1231	4.0750	6.8448	68.1250	0.7408	2.4220	5.1035	1.4459	4.7760	8.7315
Non-professional advisor	1288	4.0421	7.8778	145.710	0.6594	2.2329	6.7786	1.3113	5.7763	9.4185
No investment	204	3.7250	12.353	197.518	0.4758	2.2278	8.6528	1.3577	6.7393	14.8482
Head self-assessed health status										
Excellent or good	3129	3.9901	7.1903	90.7126	0.6392	2.2664	6.2701	1.2441	4.7956	9.2162
Fair or poor	648	4.1797	8.3605	109.760	0.8425	2.3138	6.3392	1.5205	6.7111	9.9557
Head expectations about the future										
Better or about the same	3183	4.0281	7.1907	82.4494	0.6919	2.3003	6.2717	1.3035	5.2395	9.4205
Worse	557	4.1557	7.5832	145.710	0.6203	2.2379	6.4411	1.2606	5.7445	9.0699
Whole sample	**3781**	**4.0566**	**7.3083**	**97.9300**	**0.6762**	**2.2867**	**6.3182**	**1.3033**	**5.3388**	**9.4487**

Note: The estimates accounts for multiple imputations and sampling weights.

Regression analysis was performed to examine the potential effects of socio-demographic characteristics on risk aversion. Since the distribution of risk aversion, wealth, and other variables is highly skewed, we report results based on a quantile regression. The first specification we consider in Table 13 includes a polynomial on the log of financial wealth, a polynomial on age, household size, and a number of dummy variables on gender, marital status, race, education, job characteristics, financial advisor recommendations, and self-assessed health status. In our regression the implicit risk aversion computed from the financial portfolio weights is (*ceteris paribus*) at its minimum when the head is about 58 years-old, and it is lower if she is more highly educated, or does not work as blue collar. Although each coefficient in the polynomial on financial wealth is not significantly different from zero, we reject the null hypothesis that both coefficients are jointly equal to zero (F-test: 18.73, p-value: 0.0001). Using unconstrained portfolios defined on total wealth (i.e., financial and real), the coefficients of the polynomial on (total) wealth are now significant and indicate that the relative risk aversion decreases for levels of wealth below 150,000 USD and increases for higher values. We also estimate the risk aversion to be significantly lower for a smaller household size, or when the head is young, non-white, less educated, or works – disregarding the job position. The relationship we find between risk aversion and education in this case is contrary to what is usually found in the literature. Interestingly, we find the dummy indicating whether the household has a financial advisor to be significantly positive at ten percent. When constraints are included risk aversion decreases within reasonable levels of wealth, and we observe a variation of sign in few variables: the risk aversion now reduces with higher education, or when the household follows the precepts of a financial advisor. There is also a variation of significance in race, household size and professional jobs (no longer significant), marital status and self-assessed health status (now significant). According to our results, risk aversion reduces for wealthy households, when there is a financial advisor, or when the head is young, married, more highly educated, works as entrepreneur, or reports a good or excellent health. Surprisingly, when we study the combined effect on risk aversion of several variables, gender is not significant.

Households do not hold real wealth only for investment purposes; the size of residential housing holding is also driven by a consumption motive. To account for this we study a second specification, where we include the ratio of home equity to total wealth among the regressors. The coefficient of the new covariate is significant and negative only in the constrained case, but all our findings do not change remarkably.

Table 13. Determinants of risk aversion (quantile regression)

	Financial wealth	Financial + real wealth			
		Unconstrained RRA		Constrained RRA	
Log (Wealth)	-0.3350	-1.7567***	-1.9379**	-0.7620***	-0.9737***
	(0.2234)	(0.0649)	(0.0784)	(0.1587)	(0.1672)
$Log^2(Wealth)/10$	0.0284	0.7370***	0.7979***	0.2068***	0.2763***
	(0.0840)	(0.0251)	(0.0295)	(0.0602)	(0.0648)
Primary residence / Wealth	-	-	-0.0367	-	-0.0266**
			(0.0219)		(0.0089)
Household size	0.0289	-0.1169***	-0.1111***	0.0431	0.0431
	(0.0680)	(0.0215)	(0.0216)	(0.0541)	(0.0563)
Age	-0.2120***	-0.0108	-0.0087	-0.0387	-0.0314
	(0.0397)	(0.0103)	(0.0100)	(0.0271)	(0.0287)
$Age^2/100$	0.1843***	0.0201**	0.0183**	0.0531**	0.0477*
	(0.0351)	(0.0094)	(0.0092)	(0.0243)	(0.0259)
Female	0.2005	0.0013	-0.0380	0.0803	0.0838
	(0.3186)	(0.0981)	(0.0923)	(0.2242)	(0.2331)
Married	0.1208	-0.0083	-0.0235	-0.4957**	-0.4789**
	(0.2531)	(0.0903)	(0.0845)	(0.2052)	(0.2153)
Non-white	0.4119	-0.1908***	-0.2191***	0.0875	0.0779
	(0.2600)	(0.0683)	(0.0672)	(0.1733)	(0.1827)
College graduate	-0.5543***	0.1943***	0.2016***	-0.8198***	-0.7838***
	(0.1819)	(0.0606)	(0.0601)	(0.1654)	(0.1761)
Entrepreneur	0.1554	-0.3552***	-0.3454***	-0.8767***	-0.8680***
	(0.2240)	(0.0818)	(0.0803)	(0.2061)	(0.2183)
Professional	0.2120	-0.2913***	-0.2852***	-0.3496	-0.4019
	(0.2762)	(0.0947)	(0.0935)	(0.2533)	(0.2513)
Blue collar	0.7767**	-0.3709***	-0.3837***	-0.5158*	-0.5290*
	(0.3214)	(0.1031)	(0.1033)	(0.2880)	(0.3030)
Agriculture or mining	0.1707	-0.0417	-0.0379	0.0897	0.0839
	(0.2938)	(0.0993)	(0.0996)	(0.2721)	(0.2792)
Manufacturing	-0.2917	0.0393	0.0294	-0.1215	-0.1176
	(0.2638)	(0.0862)	(0.0879)	(0.2226)	(0.2234)
Trade	-0.1794	0.1237	0.1146	-0.1817	-0.1526
	(0.2924)	(0.0880)	(0.0888)	(0.2230)	(0.2342)
Finance	0.1230	-0.0525	-0.0646	-0.2587	-0.2258
	(0.2505)	(0.0825)	(0.0813)	(0.2174)	(0.2153)
With financial advisor	-0.0839	0.0965*	0.0959*	-0.2581**	-0.2533*
	(0.1497)	(0.0509)	(0.0513)	(0.1288)	(0.1342)
Fair / poor health	0.1950	-0.0821	-0.0935	0.3099*	0.2873
	(0.2579)	(0.0677)	(0.0688)	(0.1733)	(0.1853)
Constant	16.2081***	13.1227***	14.4083***	12.3509***	13.6651***
	(1.6673)	(0.4302)	(0.5219)	(1.0349)	(1.1224)
Minimum obs	3255	3781	3781	3781	3781
Mult. Imp. Minimum dof	9.6	73.5	2.2	69.5	4.4

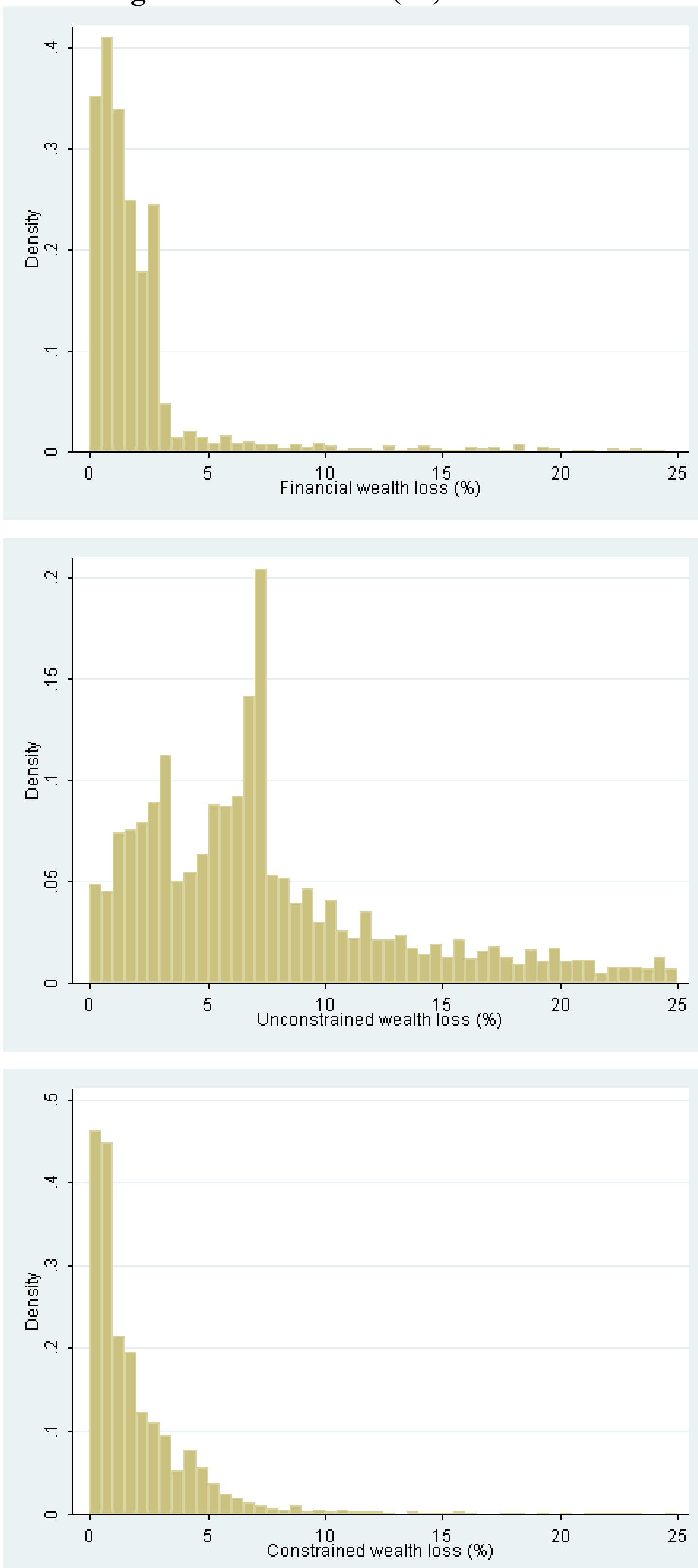
Note: The estimates accounts for multiple imputations.
****: significantly different from 0 at 1 percent; **: at 5 percent; *: at 10 percent.*

6. A lower bound to the wealth loss due to sub-optimal portfolio allocation

6.1. Wealth loss heterogeneity

With the implicit risk aversion we compute the sample counterpart of the compensative variation in equation (5). This measure is a lower bound to the wealth loss due to sub-optimal portfolio allocation. The lower bound we estimate from the aggregate portfolio for a representative agent is 0.9640 percent with the financial wealth, and 4.9662 percent with the financial and real wealth; our estimate reduces to 3.1766 if we consider constraints to portfolio composition (see Table 5). When we compute this measure for each observation in our sample (see Figure 5), we find that it is still concentrated within small values using our narrower definition of wealth, with a median of 1.3889 percent per year. This result is in line with findings in Calvet et al. (2006). Estimates are markedly larger when we include real wealth in our definition (with a median of 7.0725 percent), suggesting that the chosen allocation of real wealth is largely inefficient. Yet this allocation may also be driven by other motives than investment, and when we incorporate constraints we find a reduction in wealth loss – with a median of 1.2261 percent per year – to levels close to the ones based on financial portfolios. Figure 6 indeed shows that, with the inclusion of constraints in the analysis, our estimates of the wealth loss lower bound in most cases reduce to negligible values. Only in few cases they are quite large, and equal or almost equal to estimates based on unconstrained portfolios. The heterogeneity of our estimates is also similar using the financial portfolio and the constrained financial and real portfolio – with 80 percent of values between 0 and 5 – while we find a much wider dispersion using the unconstrained financial and real portfolio – with 80 percent of values now ranging between 1.8930 and 28.6090. In a limited number of cases we obtain a 100 percent wealth loss associated to portfolios with extremely negative weights in government bonds.

Figure 5. Wealth loss (%) distribution



Note: we exclude the cases of wealth loss >25 percent.

Figure 6. Comparison between wealth loss estimates

Note: we exclude the cases of wealth loss >25 percent.

Table 14 reports the estimated wealth loss percentiles by portfolio composition. We see that the measure based on the constrained portfolio is generally lower when at least a constraint is binding. This holds true especially with respect to the constraint on real wealth, where we estimate a median wealth loss of 1.0293 percent if real wealth includes only the primary residence, and 4.0755 percent otherwise. Households with constrained portfolios are seen as more risk averse because they choose not to participate in some risky asset markets (see Table 8). When risk aversion is larger, the choice of the optimal portfolio is made excluding high-risk combinations of assets. This reduction of the space of feasible portfolios leads to optimal portfolios that are at most as efficient as those with lower risk aversion coefficients. In this case the wealth loss measured from the comparison between observed and optimal portfolios is at most as high as for highly risk averse households.

Table 14. Wealth loss (%) by portfolio composition

	Obs.	Financial wealth			Financial + real wealth					
		Unconstrained loss						Constrained loss		
		10^{th}	50^{th}	90^{th}	10^{th}	50^{th}	90^{th}	10^{th}	50^{th}	90^{th}
Deposits										
= 0	121	2.8657	2.9797	2.9797	3.0554	7.2223	25.3424	0.0019	0.5766	3.0554
> 0	3660	0.2693	1.3652	4.0791	1.8526	7.0248	28.6664	0.1456	1.2640	4.7308
Government bonds										
≤ 0	2641	0.2317	1.8274	11.3310	3.0694	8.6637	34.0086	0.0767	1.1866	5.3050
> 0	1140	0.3098	1.2057	2.6661	1.0112	3.1724	6.6196	0.5444	1.2648	3.0554
Corporate bonds										
= 0	2250	0.0019	0.0171	0.0637	2.1964	7.2690	32.8530	0.0607	0.7970	4.8674
> 0	1531	0.3369	0.9977	2.3841	1.4940	4.9520	16.4358	0.6167	1.6731	4.3338
Stocks										
= 0	1399	0.0784	1.5445	9.6226	2.3808	7.4778	37.4530	0.0361	0.5659	4.6774
> 0	2382	0.4226	1.3356	2.8992	1.7546	5.6963	19.9130	0.6337	1.8375	4.6558
Real wealth										
= primary residence	2337	-	-	-	1.6965	7.1229	31.3090	0.0744	0.7215	2.9809
> primary residence	1444	-	-	-	2.8195	6.8945	17.3658	1.7388	4.0755	7.5344
Binding constraints										
At least one	2977	0.1860	1.7034	6.3659	1.8930	7.1648	29.6108	0.1105	1.0293	4.5855
No constraint	804	0.3350	0.9850	2.3798	1.9999	5.3015	13.6258	1.5075	3.0679	6.3488
Whole sample	**3781**	**0.2749**	**1.3889**	**4.0546**	**1.8930**	**7.0725**	**28.6090**	**0.1268**	**1.2261**	**4.6753**

Note: The estimates accounts for multiple imputations and sampling weights.

Table 15 shows how the lower bound of wealth loss varies with wealth in income quintiles. Wealth loss seems to reduce with wealth and income when we neglect constraints, and to increase when we incorporate them in the analysis. These results suggest that wealth loss may be low with more highly diversified portfolios (compare indeed with Table 9).

Table 15. Wealth loss (%) by wealth and income quintiles

	Obs.	Financial wealth			Financial + real wealth					
		Unconstrained loss						Constrained loss		
		10^{th}	50^{th}	90^{th}	10^{th}	50^{th}	90^{th}	10^{th}	50^{th}	90^{th}
Wealth quintiles										
I	757	0.3061	2.3567	17.8054	0.8865	7.2383	59.9560	0.0475	1.1265	6.0782
II	756	0.1894	1.2248	2.9424	4.7474	9.1508	24.0016	0.0533	0.6066	4.3390
III	756	0.1970	1.1471	2.6523	2.7654	6.4645	12.6280	0.3846	1.2941	4.3811
IV	756	0.4218	1.2618	2.4659	1.7484	4.5316	8.7778	0.6777	1.9663	4.6599
V	756	0.3970	1.0770	2.6549	0.9020	2.9608	7.1641	0.7316	2.3028	4.5163
income quintiles										
I	760	0.1679	1.5244	4.4740	1.4660	6.7888	23.4052	0.0722	0.5972	3.9265
II	756	0.2780	1.3404	5.0703	2.0570	7.2117	35.8650	0.0769	1.1026	4.9184
III	757	0.3091	1.3473	3.9652	2.1622	7.8499	29.6960	0.1329	1.4449	5.2746
IV	753	0.3624	1.3057	2.8444	2.1370	6.9730	19.6050	0.3867	2.0699	5.0439
V	755	0.4388	1.1505	2.6613	1.5307	4.2792	9.4696	0.8754	2.6418	4.9007
Whole sample	**3781**	**0.2749**	**1.3889**	**4.0546**	**1.8930**	**7.0725**	**28.6090**	**0.1268**	**1.2261**	**4.6753**

Note: The estimates accounts for multiple imputations and sampling weights.

Finally, Table 16 presents the 10^{th}, 50^{th}, and 90^{th} percentiles of the distribution of the wealth loss separately for socio-demographic characteristics. There seems to be quite a strong link between wealth loss and age, race, and employment status. The measure we estimate is lower for households whose head is older, white, or does not work, whatever definition of portfolio we consider. When we account for constraints on portfolio composition, the measure is also lower when the household head is female, not married, less highly educated, reports to make no investment, declares a fair or poor health status, or negative expectations about the future. The interpretation of these findings is not straightforward as there are two potential sources of wealth loss: from i) under-diversification of risky assets, as discussed above, and ii) non-participation in risky asset markets. Intuitively, our framework interprets households with more conservative portfolios as more risk averse. Optimal portfolios of such households are specialized in few low-risk assets. Since observed and optimal portfolio allocations are similar, our estimate of the wealth loss is thus lower. This second 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 wealth loss.

6.2. Wealth loss and risk aversion

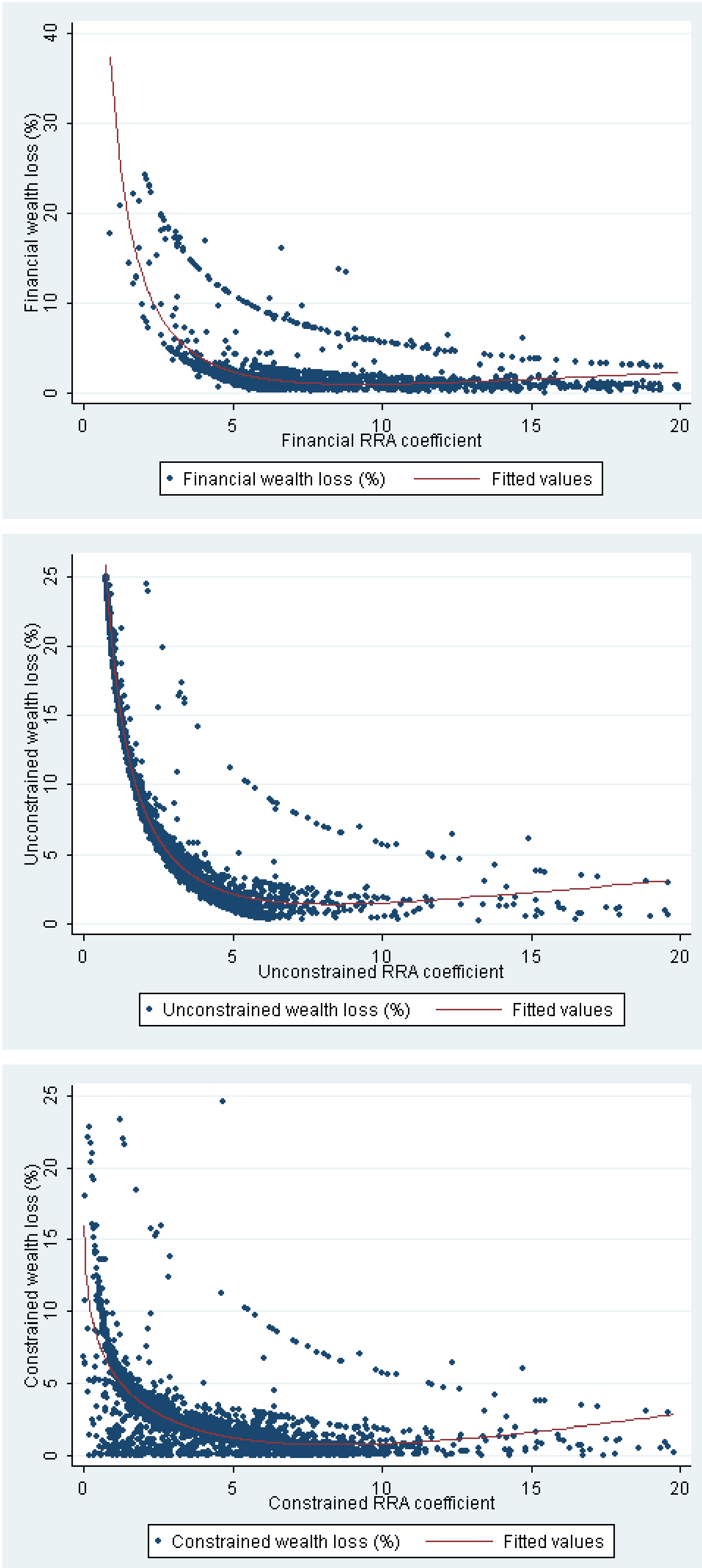
Conditional on agent's implicit risk aversion, the lower bound of wealth loss is indicative of the optimality of the observed wealth allocation. We are interested in investigating the relationship between the coefficient of relative risk aversion implicit in portfolio choices and the optimization error; Figure 7 shows that the lower bound reduces when the household is more risk averse. In the extreme case, infinitely risk averse households can and do invest only in risk free assets. The lower bound of the wealth loss associated with their portfolio is thus equal to zero. In the constrained case, the lower bound is concentrated around zero when constraints are binding. If we focus only on portfolios for which the constraint on real wealth is not binding, however, we observe the same negative relationship as with other portfolio definitions (Figure 8).

Table 16. Wealth loss (%) by households' characteristics

	Obs.	Financial wealth			Financial + real wealth					
		Unconstrained loss						Constrained loss		
		10th	50th	90th	10th	50th	90th	10th	50th	90th
Number of household members										
1	720	0.1784	1.3776	3.0323	1.3592	5.9032	20.4560	0.2400	1.2127	4.3679
2	1498	0.2955	1.3274	2.9797	1.8930	6.5335	21.1102	0.1755	1.3393	4.5646
More than 2	1563	0.3113	1.4810	6.5226	2.9237	9.1507	35.4000	0.0673	1.0919	5.1431
Head age										
<36	522	0.1719	1.4821	5.9708	0.8725	10.4070	48.3090	0.0961	1.5416	6.3488
36-50	1197	0.3333	1.5312	7.2054	2.9121	9.2764	31.0672	0.0641	1.2336	5.1735
51-65	1283	0.3795	1.2815	2.9797	2.1007	6.5670	17.1380	0.1969	1.3810	4.6164
66-80	636	0.1584	1.1508	2.8724	1.8259	5.6113	10.0711	0.2984	0.9131	3.7621
>80	139	0.1393	1.2299	2.7236	1.5639	5.0021	7.2038	0.3496	0.6740	2.9070
Head gender										
Male	3125	0.2989	1.3702	4.1833	2.0087	7.1817	28.3364	0.1417	1.2942	4.9674
Female	656	0.1797	1.4914	3.3087	1.6018	6.7768	28.6900	0.0884	0.9760	4.0902
Head marital status										
Not married	1091	0.1820	1.4430	3.3163	1.4466	6.7718	29.0664	0.0967	1.0683	4.3643
Married	2690	0.3085	1.3651	4.2156	2.2584	7.2223	28.0660	0.1415	1.3042	5.0046
Head race										
White	3136	0.2936	1.3464	3.4862	1.8861	6.7929	27.3726	0.1579	1.2744	4.6056
Non-white	496	0.2063	1.6743	7.2432	2.0463	7.6082	35.4000	0.0444	0.6874	5.1869
Head education										
High school or below	1322	0.1940	1.4487	5.6099	2.1615	7.1891	28.1850	0.0698	0.6873	4.5711
College or above	2459	0.3122	1.3633	3.4270	1.7985	6.8586	28.6864	0.1969	1.6809	4.8674
Head employment status										
Not worker	869	0.1940	1.3067	2.9526	1.6634	5.5341	12.3914	0.2669	0.9560	3.6715
Employee	1827	0.3034	1.4542	5.8594	2.0338	8.2467	36.8970	0.0840	1.2686	5.1735
Self-employed	1112	0.2836	1.2000	3.3120	2.1026	6.8525	19.4936	0.2517	1.7864	5.5927
Head primary job position										
Entrepreneur	1696	0.3083	1.3998	4.2156	2.0675	7.4586	28.8828	0.1718	1.8299	5.2550
Professional	662	0.2859	1.4152	5.1336	1.7327	7.2690	35.7980	0.0995	1.1603	5.0046
Blue collar	575	0.2510	1.4565	7.9446	2.6553	8.6575	35.7990	0.0395	0.8059	5.3081
Head kind of business-industry										
Agriculture or mining	358	0.2312	1.5642	10.1480	3.0554	8.9619	34.8350	0.0478	0.7714	5.5928
Manufacturing	400	0.3245	1.5020	6.0711	2.5355	7.6928	33.3610	0.1161	1.3135	4.8527
Trade	401	0.2474	1.4184	5.2685	1.3211	7.0209	23.6590	0.1297	1.1926	4.7206
Finance	480	0.3458	1.3723	4.2156	1.3581	7.4062	28.6864	0.1096	1.5028	5.7520
Services or p.a.	1290	0.2971	1.3880	4.8293	2.1007	8.0968	35.4000	0.1029	1.5226	5.2550
Investment advisor										
Media	801	0.3069	1.4440	3.4270	1.7213	7.0329	33.1860	0.1366	1.6471	5.1851
Professional advisor	1231	0.3157	1.3071	3.4970	1.9267	6.5825	25.3596	0.1764	1.3051	4.4484
Non-professional advisor	1288	0.2230	1.4158	4.4428	1.8668	7.2054	28.6750	0.1044	1.0334	4.6484
No investment	204	0.1567	1.5011	7.1504	2.0564	7.2036	30.2306	0.0253	0.5755	4.4002
Head self-assessed health status										
Excellent or good	3129	0.2780	1.3876	3.9652	1.8668	7.1275	29.2970	0.1454	1.3552	4.8750
Fair or poor	648	0.2438	1.3922	4.0546	1.9555	6.9797	23.5928	0.0767	0.6371	4.3413
Head expectations about the future										
Better or about the same	3183	0.2989	1.3889	3.9652	1.8861	7.0252	28.1850	0.1401	1.2639	4.6467
Worse	557	0.1784	1.3923	5.2685	1.9604	7.2036	30.2306	0.1087	0.8429	5.1657
Whole sample	**3781**	**0.2749**	**1.3889**	**4.0546**	**1.8930**	**7.0725**	**28.6090**	**0.1268**	**1.2261**	**4.6753**

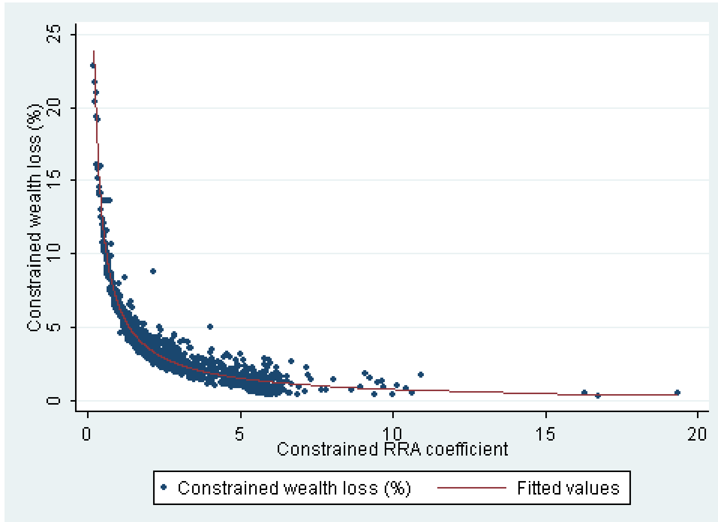
Note: The estimates accounts for multiple imputations and sampling weights.

Figure 7. Wealth loss and RRA



Note: we exclude the cases of RRA >20 or wealth loss >25 percent.

Figure 8. Wealth loss and RRA, non-binding constraint on real wealth



Note: we exclude the cases of RRA >20 or wealth loss >25 percent.

Table 17 reports the percentiles of wealth loss by risk aversion quintiles. Interestingly we find that in our sample, not only wealth loss reduces with risk aversion, but also it varies less when households are more risk averse. Let us focus on financial wealth only; while the difference between 90th and 10th percentiles is 25.12 p.p. in the group of the least risk averse households, it is just 1.74 p.p. in the group of the most risk averse. Similarly, in the constrained case this difference reduces from 9.99 to 1.58 p.p. moving from the lowest to the highest risk aversion quintile. This evidence supports our argument that, the more risk averse the household, the smaller the space of asset combinations feasible for the optimal portfolio, and so the more concentrated the wealth loss.

Table 17. Wealth loss (%) by implicit RRA quintiles

	Obs.	Financial wealth			Financial + real wealth					
		Unconstrained loss						Constrained loss		
		10th	50th	90th	10th	50th	90th	10th	50th	90th
Implicit RRA quintiles										
I	757	2.0549	2.8641	27.1790	13.1670	22.1634	60.1634	0.5992	4.5930	10.5894
II	756	0.7571	1.7025	2.9797	7.1539	8.1669	10.9261	0.3593	2.6466	4.0384
III	756	0.5304	1.3899	2.7166	4.8833	6.1135	6.9586	0.1507	1.5849	2.3412
IV	756	0.4218	1.1661	3.9652	2.2474	3.3404	4.9353	0.4464	0.6586	2.0793
V	756	0.0239	0.5222	1.7627	0.3652	1.6945	3.1346	0.0380	0.4608	1.6222
Whole sample	**3781**	**0.2749**	**1.3889**	**4.0546**	**1.8930**	**7.0725**	**28.6090**	**0.1268**	**1.2261**	**4.6753**

Note: The estimates accounts for multiple imputations and sampling weights.

7. Concluding remarks

In this paper we propose an estimation strategy for the coefficient of relative risk aversion based on the level that minimizes the one-period wealth loss incurred with sub-optimal portfolio allocations. We apply this strategy to US SCF data under several definitions of portfolio. In our preferred definition wealth includes financial and real assets, and households face constraints on portfolio composition. They cannot borrow against financial assets and they must take as fixed the holding of residential housing. By doing so we take into account two crucial characteristics of the investment in the house of residence: i) transaction costs are so high that such a portfolio position may be considered as completely illiquid in the short run, and ii) there are relevant consumption rather than investment motives in the housing tenure choice.

Our estimates of the household specific relative risk aversion parameters show that there is a substantial heterogeneity in the preference parameter. In our preferred case the median RRA parameter equals 5.3, and 80 percent of the households lie between 1.3 and 9.4. Relying on a representative agent approach can be severely misleading because the corresponding estimate for the aggregate portfolio is 2.3. Many of the correlations between risk aversion and the observable characteristics of the households are intuitive and in agreement with earlier studies; we find a lower risk aversion for wealthier households, when the portfolio is managed following the recommendations of a financial advisor, or when the head is young, married, more highly educated, works as entrepreneur, or reports a good or excellent health. Contrary to some of the evidence presented by previous empirical works, in our analysis neither gender nor race play a significant role.

Although we find several strong correlations, the direction of causality is difficult to ascertain for some variables. While for characteristics such as age, gender, and race there is not any problem of reverse causality, for other socio-economic status the causality link with risk aversion is potentially debatable. Unemployment, wealth, education, marital status, the presence of a financial advisor and even the health status may be affected by agent's risk aversion.

We also provide evidence on the monetary loss caused by sub-optimal portfolios, conditional on the level of risk aversion. We show that the lower bound of such sub-optimality cost ranges between 0.12 percent to 4.67 percent of the total wealth for 80 percent of the households when we consider the constraints on portfolio choice. For half of the households the loss is lower than 1.2 percent of their wealth. It is worth noting that the loss is higher for the richer families and it is reduced for those households with severely constrained (and simplified) portfolios.

More risk averse households are those who suffer a smaller wealth loss due to sub-optimal portfolio. When we look in more detail at the mechanism which determines this result we see that (i) the higher the risk aversion the fewer are the assets included in the *optimal* portfolio, and (ii) the higher the risk aversion the fewer are the assets included in the *observed* portfolios. As the wealth loss due to sub-optimality is positively related to the difference between actual and optimal portfolio points (i) and (ii) above justify the empirical results.

Our approach is based on several standard assumptions. We assume that investors make their choice maximizing an expected utility function, follow a "buy-and-hold" strategy, and use CRRA utility functions. We further require that the prices of the primitive assets follow a geometric Brownian motion. Under these assumptions, the portfolios that maximize the expected utility function coincide with those resulting from a standard mean-variance framework. The advantages of this approach are that it offers a metric to compare portfolios in the presence of constraints on their composition, which may be relevant if substantial real wealth is present, and that it allows to study the distribution of the preference parameter in the population.

There are at least two main directions for future research: the analysis of the links between relative risk aversion, observable characteristics and wealth loss deserves further efforts in order to solve the problems of reverse causality discussed above; from the theoretical point of view it is interesting to evaluate the possibility to apply the "compensative variation approach" in a multiperiod framework, closer to the life-cycle models of asset allocation.

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