Netspar Network for Studies on Pensions, Aging and Retirement

Alessandro Bucciol

Raffaele Miniaci

Household Portfolios and Implicit Risk Preference

Discussion Paper 07/2008 - 036

March 30, 2010 (revised version from July 25, 2008)

HOUSEHOLD PORTFOLIOS AND IMPLICIT RISK PREFERENCE*

ALESSANDRO BUCCIOL†
University of Verona, University of Amsterdam, and Netspar

RAFFAELE MINIACI
University of Brescia

This draft: March 30 2010

Abstract

We derive the distribution of a proxy for the risk tolerance in a representative sample of US households. Our measure is deduced from the willingness to bear risk as indicated by the variance of returns of each household's observed portfolio. The estimates, obtained assuming constraints on portfolio composition, show substantial heterogeneity across households. We find risk tolerance to reduce with age and increase with wealth. Other variables such as education, gender, race and household size do not have instead a significant relation with risk attitude. Our findings are robust to changes in portfolio definition, asset returns and sample composition.

Keywords: risk preference, household finance, constraints, real estate, human capital.

JEL classification codes: D81, G11, D14.

---

* An earlier version of this paper circulated as "Household Portfolios and Implicit Risk Aversion", Netspar DP 07/2008-036, 2008. We are grateful to the editors and two anonymous referees for their comments and suggestions. We further thank Pierluigi Balduzzi, Guglielmo Weber and the seminar participants at the NASM 2008 and ICEEE 2009 Conferences, and the Universities of Padua, Pavia, and Verona. Financial support from MIUR (PRIN 2005, grant no. 2005132539_001) is gratefully acknowledged. The usual disclaimers apply.

† *Corresponding author*: Alessandro Bucciol, University of Verona, Dept. of Economics, Viale dell'Università 3, 37129 Verona, Italy. Telephone: +39 045.842.5448. Fax: +39 045.802.8529. Email: alessandro.bucciol@univr.it.

1. Introduction

Individuals often face problems under uncertainty, and understanding their attitude toward risk is essential to predict economic behavior. In this paper we provide new insights on the distribution of risk preferences across US households and study the correlation between risk tolerance and the main household socio-demographic characteristics. We estimate risk preferences from the willingness to bear risk of each household in our sample (Survey of Consumer Finances, wave 2004), as indicated by the variance of the returns of the observed portfolio made of financial, real and human assets, and under various assumptions on portfolio constraints. In the absence of constraints, our estimate is proportional to the standard deviation of the observed portfolio returns.

A large body of literature already estimates the distribution of risk preferences from data on wealth allocation. Previous works base their analysis on the portfolio share held in risky assets, assuming that the observed share is the result of a mean-variance optimizing behavior. We depart from previous works in three directions. The first is methodological. We distinguish between observed and mean-variance efficient portfolios. For each household we construct the efficient portfolio with the same variance as the observed portfolio. The difference between the two portfolios may depend on investment mistakes, information costs, inadequate model assumptions (see Campbell, 2006), or biased estimates of the returns. Our estimate of risk preference makes this difference as small as possible.

Our remaining departures concern the definition of portfolio. We consider a broad definition, with a distinction between deposits (risk free), bonds, stocks, human capital and real estate. Earlier studies take into account only financial assets, frequently grouped into one broad category, or financial assets and human capital. We however believe that it may be more realistic to account for the different asset characteristics and at least distinguish between subcategories of financial assets. The size of real estate and its related liabilities, furthermore, is not negligible in household portfolios and ignoring them may bias the analysis, since house price risk generates hedging needs (Flavin and Yamashita, 2002; Pelizzon and Weber, 2008) and crowds out stock holdings (Cocco, 2005).

Finally, we include constraints on efficient portfolio weights. In particular, we assume that the stock of human capital is fixed and cannot be changed in our static framework. Constraints are relevant also for real estate. Individuals indeed hold owner-occupied housing for investment as well as consumption purposes. Since housing consumption demand will typically not equal investment demand, an owner-occupier distorts the housing investment to bring it into equality with housing consumption. To correct for the potential bias due to the housing consumption motive, we follow Flavin and Yamashita (2002) and take the holding of (owner-occupied) residential housing as exogenous. An optimizing agent in our problem thus chooses the portfolio allocation conditional on the wealth held in residential housing. We complete our analysis including three further constraints that are likely to hold at the individual level. We require that mortgages cannot exceed the value of real estate; 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 elsewhere. This is enough to eliminate a private investor with just mildly negative beliefs (Figlewski, 1981). The inclusion of constraints also reduces potential errors in measurement of the efficient portfolio (Green and Hollifield, 1992).

Our estimates of the preference parameter show substantial heterogeneity across individuals. In our preferred case we find risk tolerance to correlate negatively with age, and positively with wealth. Our results suggest that education, gender, race, and household size do not play a significant role once we control for other variables.

An analysis based on household survey portfolio data is disturbed by unobserved transaction costs, minimum investment requirements and other market imperfections. These issues affect households in different ways; therefore the heterogeneity we observe in portfolio composition reflects differences in both risk preferences and market conditions. In fact, in our regression analysis we find a significant effect of variables that may proxy financial sophistication as well as transaction costs. Transaction and entry costs, however, should be less important among the wealthier individuals (Calvet et al., 2009). In the sub-sample of the 20 percent wealthiest households we observe similar correlations for demographic and wealth variables, and lower or insignificant correlations for the proxies of financial sophistication and transaction costs; this evidence seems to suggest that transaction costs are not the main driver of our results.

The remainder of this paper is organized as follows. Section 2 surveys the literature on risk preferences. Section 3 presents our framework. Section 4 describes our survey data (Survey of Consumer Finances, wave 2004) and time series data (covering quarterly the years 1980-2004). Section 5 reports our benchmark estimates for the portfolio of a representative agent and the distribution of portfolios in the sample. Section 6 shows the main results of a sensitivity analysis on the return time series. Finally, Section 7 concludes. In the Appendix we discuss the link between our approach and the certainty equivalent returns, the construction of the portfolios from the survey data and the estimation of the human capital.

2. Previous findings on risk preferences

The analysis of risk preferences from observed choice data has been running in a number of economic environments, from labor supply decisions (Chetty, 2006) to property/liability insurances (Szpiro, 1986), from television shows (Beetsma and Schotman, 2001) to auto insurance contracts (Cohen and Einav, 2007) and in the laboratory (Schubert et al., 1999; Choi et al., 2007). The two main strands of this literature, however, focus on consumption and investment choices.

One strand is based on non-durable consumption data. According to the Consumption-CAPM framework, consumption choices are fully characterized by the Euler equation, as a function of the choice in the previous year, market returns and household's specific preference parameters. To obtain an estimate of the risk aversion parameter, one should use panel datasets with a long history of household consumption data. Since such datasets are not available, two solutions have been adopted over the years: running the analysis *i)* using time series of macroeconomic statistics, assuming that there is a representative agent (see Hansen and Singleton, 1983; Mehra and Prescott, 1985; Campbell, 2003), and *ii)* using pseudo-panels created from repeated cross-section survey data, grouping together individuals belonging to the same birth cohort (see Attanasio and Weber, 1995; Blundell et al., 1994). While the estimate of the risk aversion coefficient is generally comprised between 2 and 7 using pseudo-panels, it can be well above 10 using time series of macroeconomic statistics.

A second strand of the literature looks at portfolio choices and is strictly related to our work. According to the static Mean-Variance (henceforth MV) portfolio framework, the investment in risky assets depends on the expected values and the covariances of their returns, and the household's specific risk preference. Since household survey data on portfolio composition are easily available, it is natural to use this approach to study the distribution of risk preferences across households. Empirical works in this field usually take the share of portfolios allocated to risky assets (as a whole or just stocks) as proportional to risk tolerance (see Cohn et al., 1975; Friend and Blume, 1975; McInish, 1982; Siegel and Hoban, 1982; Morin and Suarez, 1983; Riley and Chow, 1992; and Shaw, 1996).

With the improvement in the accuracy of survey data, researchers have devised hypothetical questions asking to compare different lotteries. A number of works used the responses to such questions to infer a measure of risk preference for each household (see, e.g., Barsky et al., 1997; Donkers et al., 2001; Guiso and Paiella, 2008; Kimball et al., 2008).

Works on the distribution of risk preference typically find a rather large heterogeneity, with the parameter correlating in particular with wealth, age, gender, and education. The correlation with wealth, however, depends crucially on the definition used. Research focusing on financial wealth seems to support a positive link with risk tolerance (Friedman, 1974; Cohn et al., 1975; Riley and Chow, 1992; Shaw, 1996), reflecting the empirical evidence of stock holdings increasing in wealth (see Guiso et al., 2001). Shaw (1996) focuses on the effect of human capital, and finds from Survey of Consumer Finances (henceforth SCF) data a positive correlation with risk tolerance. Friend and Blume (1975) also find evidence of a positive relation from a precursor of the current SCF, but only when owner-occupied housing is excluded from their definition of wealth. Siegel and Hoban (1982) find from US National Longitudinal Survey data patterns consistent with increasing or constant risk tolerance using narrow definitions of wealth, and patterns consistent with decreasing risk tolerance using broader definitions of wealth, including housing and non-marketable assets. Morin and Suarez (1983) draw similar conclusions using the Canadian SCF and including human capital in the definition of wealth. Financial, human and real holdings are however very different assets with different degrees of liquidity. One may expect different results from an analysis that takes into account constraints on portfolio holdings.

In general, there seems to be consensus on the relation between risk tolerance, age, gender and education. The majority of the empirical studies have found that risk tolerance reduces with age (see McInish, 1982; Morin and Suarez, 1983; Palsson, 1996), is lower for women (see Palsson, 1996; Halek and Eisenhauer, 2001; and the literature review in Croson and Gneezy, 2009) and less highly educated individuals (see in particular Riley and Chow, 1992; and Halek and Eisenhauer, 2001).

It is not clear whether these correlations hold as such, or are instead capturing correlations with other variables omitted from the analysis. For instance, one might observe a correlation between risk preference and education whereas the true correlation is between risk preference and financial sophistication (Guiso and Jappelli, 2005). The observed correlation might arise just because more sophisticated individuals are also more highly educated on average. With this paper we aim to shed further light on this issue, using portfolio choice data and considering a richer specification to include the main demographic, social, and economic variables of a household.

3. Framework

Our economy includes one risk free asset and a set of n risky assets with vector of expected excess returns η and covariance matrix Σ; (e,S) consistently estimate the true asset return moments (η,Σ).

For each household $i, i=1,...,N$ with its specific Risk Tolerance (RT) coefficient γ_i we compute the MV efficient portfolio of weights $w_i(\gamma_i)=\left[w_{i,1}(\gamma_i) \quad w_{i,2}(\gamma_i) \quad \dots \quad w_{i,n}(\gamma_i)\right]'$. We assume that the household's observed portfolio of weights $\omega_i=\left[\omega_{i,1} \quad \omega_{i,2} \quad \dots \quad \omega_{i,n}\right]'$ proxies the efficient one of weights $w_i(\gamma_i)$. In other words, we allow the observed portfolio to deviate from the efficient one for investment mistakes, market imperfections or incomplete information about the household's risk type. More trivially, the two portfolios may differ because of incorrect estimates of (e,S) or inadequate model assumptions.

Our RT estimate is the value of γ_i implicit in the following equation, which imposes an identity in the variance of the returns on the two portfolios:

$$(1) \qquad w_i(\gamma_i)' S w_i(\gamma_i) = \omega_i' S \omega_i.$$

Figure 1 shows our metric in a mean-standard deviation plan. With our approach we compare the two portfolios A and B. One could argue, however, that there is no specific reason to look at portfolio variances, and we could also look at, for instance, portfolio expected returns. In this case we would compare portfolios A and C of the figure. More generally, any portfolio along the efficient frontier is a potential candidate for our comparison. It is important to notice that efficient portfolios with lower (higher) variance of returns than the observed portfolio have a larger (smaller) holding of risk free assets than the efficient portfolio we consider. Using them in the comparison would therefore generate a lower (higher)

RT estimate. We however believe that the variance of an observed portfolio is a stronger indicator of the household's willingness to bear risk. There are two further reasons why one may want to look at the portfolio variance. First, the variance is more robust to estimation errors than the expected return (see, e.g., Merton, 1980; Chopra and Ziemba, 1993); second, our approach is consistent with the analysis in terms of Certainty Equivalent Returns (CER) from standard expected utility theory (as in Calvet et al., 2009; see Appendix A.1).

We call "expected return gap" the difference in the expected returns of the two portfolios,

(2) $$\rho_i = e'\left(w_i\left(\gamma_i\right) - \omega_i\right).$$

This statistic has at least four possible interpretations. It can be seen as the lower bound of the optimization bias, incurred when choosing the observed portfolio ω_i rather than its efficient alternative w_i due to investment mistakes, the lack of rationality or financial sophistication. The gap may also indicate the cost of market imperfections, in which agents deviate from the optimal behavior because of transaction or information costs. Third, the gap may inform on the imprecision in the estimate of the efficient portfolio due to errors in the asset moments. A final possible interpretation is a measure of how close our framework is to the actual behavior.

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

(3) $$w_i = \gamma_i S^{-1} e,$$

in which case the expected return gap is

(4) $$\rho_i = \left(e'S^{-1}e\right)^{1/2}\left(\omega_i' S \omega_i\right)^{1/2} - \omega_i' e.$$

Substituting (3) in (1), we solve the identity for γ_i and obtain that risk tolerance is proportional to the standard deviation of the returns on the observed portfolio:

(5) $$\gamma_i = \left(\frac{\omega_i' S \omega_i}{e'S^{-1}e}\right)^{\frac{1}{2}}.$$

Investors, however, usually face constraints to their portfolio allocation. We consider equality and inequality constraints on portfolio composition, described for a generic portfolio of weights x by the conditions

(6) $$Ax = b$$

(7) $$Cx \leq d$$

In general, the problem has no closed-form solution, and the solution is found numerically with quadratic programming[1]. A closed-form solution to our problem is available under only equality constraints (6). In this case it turns out that the efficient portfolio has weights

(8) $$w_i = \gamma_i Q + q$$

with

(9) $$Q = \left(I - S^{-1}A'\left(AS^{-1}A'\right)^{-1}A\right)S^{-1}e$$
$$q = S^{-1}A'\left(AS^{-1}A'\right)^{-1}b$$

and we estimate risk tolerance from

(10) $$\gamma_i^2 = \frac{q'Sq - \omega_i'S\omega_i}{Q'SQ - 2Q'e}.$$

This measure is strictly positive as long as $b \neq 0$. To get an intuition consider the simple case of constraints requiring that a subset x_c of f weights are fixed, that is, $x' = \left[x_u' \quad x_c'\right]$ and (6) rewrites as

(11) $$Ax = \begin{bmatrix} \underset{f\times(n-f)}{0} & I_f \end{bmatrix}\begin{bmatrix} x_u \\ x_c \end{bmatrix} = \omega_c.$$

where I_f is a $f \times f$ identity matrix. In this case the optimal weights are given by

(12) $$w_i = \begin{bmatrix} w_{i,u} \\ w_{i,c} \end{bmatrix} = \begin{bmatrix} \gamma_i\left(S_{uu}\right)^{-1}e_u - \left(S_{uu}\right)^{-1}S_{uc}\omega_c \\ \omega_c \end{bmatrix}$$

with e_u and S_{uu} expected excess returns and covariance matrix of the unconstrained assets, and S_{uc} covariance matrix between unconstrained and constrained assets. Efficient allocation of the unconstrained portfolio weights accounts for an additional hedge term $S_{uu}^{-1}S_{uc}\omega_c$ depending on the variance of the unconstrained assets, the covariance between unconstrained and constrained assets, and the holding of constrained assets ω_c. Notice that equation (12) is independent from the expected excess returns and the variance of the constrained assets. A household with holdings only in risk free and constrained assets has in

[1] We use the function `quadprog` in Matlab.

this framework a positive RT coefficient, because it does not make further investments to hedge against the risk associated to the constrained wealth.

4. Data

4.1. Household portfolios

In order to estimate the risk tolerance parameter within the framework described above, we need detailed information on wealth allocation for a representative sample of households. Banks and fund managers may provide detailed data on financial portfolios of their customers, but usually these datasets are not representative of the whole population. Furthermore, they typically ignore human capital and real estate, which are likely to influence households' decisions. An obvious candidate dataset for our purpose is therefore the US Survey of Consumer Finances (SCF). The SCF is a repeated cross-sectional survey of households conducted every three years on behalf of the Federal Reserve Board. It collects detailed information on assets and liabilities, including home ownership and mortgages, together with the demographic characteristics of a sample of US households. The survey deliberately over-samples relatively wealthy households to produce more accurate statistics; sampling weights are then provided to obtain unbiased statistics for the US population. The SCF also 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 imputations of missing data increase the efficiency of estimation, allowing the researcher to use all available information, and have 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.

Our data on household portfolio holdings are taken from the wave 2004 of the SCF (4,519 observations). We consider two definitions of portfolio. The "narrow" definition includes the main financial assets, which we aggregate in three categories: deposits, bonds, and stocks. The "broad" definition also includes human capital, real estate, and their related liabilities. In this case we add two further categories (human wealth and real estate). From the sample we drop the households with missing information on financial wealth (296 cases) or income (103 cases), and the households whose portfolios do not respect the constraints we define below in Section 4.2 (25 cases). Our final sample consists of 4,095 households.

The distribution of household wealth changes markedly using either definition (top part of Table 1). While we find a median value of 11,000 USD using the narrow definition, the median is 52,338 USD using the broad definition net of human capital (and 141,300 USD also including human capital).

Each asset is classified as defined in Table 1; for details on the calculation of portfolio weights see the Appendix Section A.2. Table 1 also reports the composition of the aggregate portfolio, computed accounting for multiple imputations and sampling weights. We observe that most financial wealth is held in stocks. Considering our broad definition, the largest share of wealth (52 percent) is held in real estate, mostly in owner-occupied residential housing (39 percent). The inclusion of mortgages in the bonds class determines an aggregate short position in it.

4.2. Portfolio constraints

We analyze three different situations: one using the narrow portfolio definition (only financial assets) without constraints (hereafter *unconstrained narrow definition*), and two using the broad definition (financial assets plus human wealth plus real estate). In one case we consider only equality constraints on human capital, that is, we assume that human capital is fixed for portfolio decisions (with a little imprecision of terminology, hereafter *unconstrained broad definition*). In the second case (hereafter *constrained broad definition*) we also consider short-selling constraints on the financial components, and equality constraints on residential housing. Specifically, our constraints are: fixed holding of human capital; no short sale in deposits, bonds and stocks; no mortgage financing for more than the value of real estate (that is, bonds cannot take a position below the opposite of real estate); investment in real estate not lower than the value of residential housing. We include constraints on housing to deal with a potential consumption motive that drives the investment in residential housing. To limit this effect, Pelizzon and Weber (2009) adjust household portfolios reducing real estate 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 of residential housing.

4.3. Asset time series

We take annual financial returns (bonds and stocks) from the "Merrill Lynch US Corporate & Government Master Index" and "MSCI USA Stock Index" time series of US asset total return indices (downloaded from Datastream). We consider as risk free return the yield of 3-month T-bills. To measure the uncertainty related to human capital we construct from Bureau of Economic Analysis (BEA) data a time series of labor income consistent with the definition we used in the SCF.[2] Our time series cover quarterly the years from 1980 to 2004 (100 observations). To compute the correlations with the asset excess returns we subtract from this series the series of our risk free returns.

It is more problematic to find a time series of real estate returns valid for our purpose. From the perspective of a household, we need a series that accounts for not only capital gains, but also earnings due to rents. This information is not available in standard indices such as OFHEO and S&P/Case-Shiller home price indices. We therefore use the "MIT-CRE Transaction-based Index of US Real Estate Investment". This index, measured since 1985 on a quarterly frequency, is based on transaction prices to avoid sources of index smoothing and lagging bias that are present in other indices (see Fisher et al., 2007). The total return index we consider incorporates returns from 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 the risk free asset. Using the largest period available for all the series (from 1985 to 2004 on a quarterly frequency), bonds dominate real estate returns in a mean-variance sense. As a consequence, no mean-variance optimizer would hold a long position in real estate, in contrast to most of the portfolios we observe in the SCF sample. To overcome this problem, one possibility is to consider a shorter period length; this case is discussed in Section 6.1. In our benchmark case we instead extend our time series length using the method suggested 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 asset moments are computed according to

[2] See the Appendix Section A.2. We take the difference between personal income and earnings from rents, dividends, and capital gains. The resulting time series incorporates wage and salary disbursements, supplements to wages and salaries, proprietors' income with inventory valuation and capital consumption adjustments, and personal current transfer receipts, less contributions for public social insurance.

Stambaugh (1997) and reported in Table 2 (panels A, B). Stocks are by far the category with the highest risk and expected excess return; their Sharpe ratio is however below the one of bonds (30 instead of 43 percent). Since in our analysis we always take the holding of human capital as fixed, the historical return on income and its variance do not matter for the computation of neither the efficient portfolio, nor RT; to matter is only its correlation with the returns on the other assets.[3] Similarly, under our constrained broad definition the historical return on real estate and its variance matter only for the portfolio choice between financial assets and real estate assets except for the primary residence.

Panel C of Table 2 shows two optimal portfolios arising from these moments. Under the narrow definition we take the tangency portfolio, and under the broad definition we compute the efficient portfolio that fulfils equation (12) with the constraint that the weight on human capital is equal to the value observed in the aggregate portfolio; we use a value of γ such that the weights on all the risky assets sum to one. This latter portfolio is more consistent to our analysis than the tangency portfolio under the broad definition, as we always keep human capital as fixed. Under our narrow definition, an efficient allocation of wealth would prescribe an investment in bonds $78.91/21.09 = 3.74$ times as large as an investment in stocks – a number sizably different from the $28.23/51.01 = 0.55$ ratio observed in the aggregate portfolio. A similar picture emerges from the optimal portfolio under the broad definition. With respect to the aggregate observed portfolio, the MV strategy would suggest increasing the investment in stocks and real estate, and (consequently) reducing indebtness.

5. Benchmark results

5.1. Risk tolerance for a representative agent

We first present a measure of risk tolerance for a representative agent in our sample. We derive the RT coefficient and the expected return gap using as observed portfolio the aggregate portfolio (whose average over the five imputations is shown in Table 1).

The first two columns of Table 3 show our estimates together with confidence intervals based on 1,000 bootstrap simulations over the household units. We obtain a RT coefficient of 0.21 from the financial portfolio definition, and 0.12 and 0.37 respectively from the unconstrained and constrained broad portfolio definition. The framework using the uncon-

[3] Importantly, this implies that idiosyncratic income risk is not relevant in our framework.

strained broad portfolio definition is the closest to the one in the Consumption-CAPM literature, as it takes into account an exogenous measure of income and does not impose any constraint on the other asset categories. Our estimate implies a risk aversion of $1/0.124 = 8.065$, which is in the lower bound of the range of estimates referring to the Consumption-CAPM and based on time series. In all the other cases, we obtain sizably smaller estimates of risk aversion (4.73 under the narrow definition, and 2.71 under the constrained broad definition), which are more in line with the micro-econometric evidence.

The second column of Table 3 reports the expected return gap of the representative agent and its confidence interval based on the same bootstrap simulations as for the risk tolerance. The return gap is 0.90 percent per year under the narrow definition, and 0.89 (0.50) percent under the unconstrained (constrained) broad definition. The gap of the narrow definition is not directly comparable with the gap of the broad definition (either constrained or not), because of the different definitions of wealth they refer to. We can instead interpret the difference $0.89 - 0.50 = 0.39$ as the annual percentage cost of facing constraints in real and financial wealth allocation under the broad definition.

5.2. Risk tolerance for each household

Focusing on the representative agent can be misleading because households may have very different preferences. We therefore investigate the heterogeneity in our sample by estimating the risk tolerance implicit in the portfolio of each household in our dataset.

When we compute the statistic for each observation in our sample, the median RT values are 0.08, 0.12, and 0.14 respectively using for portfolio the financial definition, the unconstrained and constrained broad definitions (third column of Table 3). Table 3 also reports below each point estimate the 2.5 and 97.5% quantiles of the sample distribution of the estimates. Only in the case of unconstrained broad portfolio definition we obtain a median risk tolerance close to the aggregate portfolio; in all the remaining cases values are around 60 percent smaller. However, the size of the coefficient varies widely across the households. Figure 3 (panel A) reports the empirical cdf of our RT estimates; under the constrained broad definition, together with a nonparametric 95 percent confidence interval (see Wasserman, 2006, page 15). Under the narrow definition, we estimate a RT of 0 for 1,162 households (36.65% of the sample once we account for sampling weights); ignoring such households the median RT in the sample becomes 0.17. In contrast, RT is always positive under the broad definition, because households hold at least deposits and human capital. Consider a household with only deposits and human capital. In this case, our approach estimates $\gamma_i > 0$ because the household does not hedge against the risk associated to income volatility (see equation 12).

Our estimates of RT vary according to the underlying assumptions on the assets space and the constraints, and are generally little correlated; in particular, the correlation between estimates under the narrow and constrained broad portfolio definitions is just 0.076. Risk tolerance increases for 1,850 households (55.76 percent of the sample once we account for sampling weights) when we consider the broad rather than the narrow definition of portfolio, and increases for 2,468 households (53.96 percent of the sample) when we take into account constraints in our broad portfolio definition. In this latter case, households with larger risk tolerance are wealthier, hold larger portfolio weights on housing, resort to mortgages more heavily, and use this additional wealth to finance their investment in stocks.

We obtain similar findings for the expected return gap (last column of Table 3). While the median gap under the unconstrained broad portfolio (0.99 percent per year) is roughly comparable to the aggregate one, the median gaps in the other two cases (0.12 and 0.04 percent under the narrow and constrained broad definitions) are considerably smaller (last column of Table 3). The empirical cdf in Figure 3 (panel B) further suggests that the expected return gap is negligible for most households under the constrained broad definition. We interpret this evidence as indicative that our framework fits the observed behavior better when real and human wealth are considered but subject to constraints.

The reasonableness of our estimates is confirmed by the comparison with the response to a question asked to all the subjects in the SCF sample. The question is the following:

> «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?»
>
> 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

Although words as "substantial" and "average" have a subjective meaning that makes any interpretation questionable, still, the variable can be seen as a rough indicator of self-assessed risk attitude. If our approach is correct, our RT estimates should then be consistent with households' self-assessment. We therefore code households who respond 1 or 2 as "risk tolerant", and households who respond 3 or 4 as "risk averse". Table 4 reports the median RT under the three definitions among the risk tolerant and the risk averse individuals in our sample. We see that 3 out of 4 respondents define themselves as risk averse, and the median RT we estimate is indeed lower in this group, apart from when we take the unconstrained broad portfolio definition. Under the narrow (constrained broad) portfolio definition, our median is indeed 0.06 (0.12) among the self-assessed risk averse households, against 0.16 (0.29) among the self-assessed risk tolerant. It is often hypothesized that risk preferences differ with individual characteristics such as age and wealth. For this reason, Table 4 also reports our statistics separately by smaller sub-groups, where we distinguish the sample by age classes and wealth quartiles.[4] Under the two relevant portfolio definitions our RT estimate is still consistent with the self-assessed measure, and is always lower among the risk averse households. Only in the lowest wealth class we do not observe a clear difference between self-assessed risk tolerant and self-assessed risk averse individuals, as our RT estimates are tiny for both.

5.3. Heterogeneity in risk preferences

To further investigate the heterogeneity of risk tolerance in the population, we perform an OLS regression analysis and examine the potential correlations between our RT measure and the economic and demographic characteristics of the households (Table 5). Our dependent variable is $\ln\left(1+\hat{\gamma}_i\right)$, where $\hat{\gamma}_i$ is the RT coefficient of household $i, i=1,...,N$ estimated from the unconstrained narrow portfolio definition, and the unconstrained or constrained broad portfolio definition. The regression equation includes age[5], the logarithm of income, the logarithm of wealth net of human capital (either the narrow or broad definition, consistently with the dependent variable), a dummy variable equal to one if children are

[4] The four wealth classes do not have the same number of observations because we construct the quartiles using the population weights. Since the SCF over-samples the wealthiest ones, we have many more observations in the uppest quartile.

[5] Using a specification with a quadratic polynomial on age, we predicted a linear age-risk tolerance profile in the relevant age range. Although in the following we will talk about 'age effect', it should be noticed that with these data we cannot disentangle age and cohort effects.

present in the household, and dummy variables for the gender, marital status (divorced, widowed, never married), race, education (high school graduate, college graduate) and occupational status (employed, self-employed) of the household head. This specification is similar to the one in Sahm (2007)[6], who estimates RT from hypothetical questions in the US Health and Retirement Study. In the same vein as Guiso and Jappelli (2005), we further include in the specification some proxies for financial sophistication: the number of financial institutions the household is involved with, and a set of four dummy variables. The dummies are worth one if: there is a regular consulting of a professional financial advisor; the head works in the finance sector; the household shops around for best rates on credit and borrowing; the household uses a computer to manage money. We also include a dummy variable for the self-assessed good or excellent health status of the head. Following Ben Mansour et al. (2008), who find a negative correlation between risk tolerance and optimism, we finally include in the specification a variable denoting the self-assessed degree of optimism of the household.[7]

The first three columns of Table 5 report the output of this regression using the three RT estimates and the full sample of households available. Note that under the narrow portfolio definition the dependent variable $\ln\left(1+\hat{\gamma}_i\right)$ coincides with $\ln\left(1+\left(\omega_i' S\omega_i / e'S^{-1}e\right)^{1/2}\right)$ where $\omega_i' S\omega_i$ is the variance of the returns of the observed portfolio held by household i. In the absence of constraints, indeed, cross-sectional differences only depend on the variance of the observed portfolio returns – which is more robust to estimation errors than the expected return (see, e.g., Merton, 1980; Chopra and Ziemba, 1993).

There is no consensus in the literature on how risk tolerance should vary with wealth; Siegel and Hoban (1982) and Morin and Suarez (1983) found for risk aversion a negative correlation with narrow definitions of wealth (financial), and a positive correlation with broader definitions of wealth (also including real and non-liquid assets). In all our regressions we find wealth to be positively correlated with risk tolerance at 1 percent significance level. Given our functional form, the elasticity of risk tolerance to wealth is equal to the

[6] Sahm (2007) focuses on cash-on-hand (wealth plus income) rather than wealth. We prefer our specification because cash-on-hand is highly correlated with income. For the same reason, we do not consider a measure of "life-cycle wealth" as described by the sum of wealth and human capital.

[7] The question asks whether "the US economy will perform better, worse, or about the same in the next 5 years". We consider optimistic who reports "better".

coefficient of $\ln(Wealth)$ times the ratio $(1+\gamma_i)/\gamma_i$. Let $\overline{\ln(1+\hat{\gamma}_i)}$ be the dependent variable sample average. If we take as a reference the average household, for which $\tilde{\gamma}=\exp\left\{\overline{\ln(1+\hat{\gamma}_i)}\right\}-1$, the estimated elasticity ranges between 0.155 of the constrained broad definition and 0.245 of the financial portfolio. As wealth moves from the 25th to the 75th percentile (see Table 1) the predicted variation $\widehat{\Delta\ln(1+\gamma_i)}$ amounts to 17% of the corresponding interquartile distance in the case of constrained broad definition (see Table 4), this percentage rises to 50% in the case of the financial portfolio. (Log)Income is negatively partially correlated with (log) risk tolerance in the unconstrained cases, but not in the broad constrained one. When human capital and real estate are considered, we estimate a significant positive effect of being divorced and a negative effect of age. However, a clear limitation of this analysis is that we cannot separate age from cohort effects.

The proxy variables for financial sophistication prove to be correlated with risk tolerance. In particular in all of the cases our estimate show that households using a larger number of financial institutions and those shopping around for better credit conditions are characterized by higher risk tolerance; when we consider the constrained broad definition, households who use a computer to manage their money are significantly more risk tolerant. Consulting or not a financial advisor, as well as being optimistic or pessimistic about future economic conditions are not correlated with the degree of risk tolerance.

After having controlled for income, wealth and financial sophistication, our estimates show a negative correlation between risk tolerance and age, but only when human capital and real estate are included in the definition of portfolio. We find instead no direct effect of gender and education on risk tolerance, and only in the case of financial portfolio there is a weak evidence in favor of the hypothesis that non-white households are less risk tolerant than average. We also tried a specification including two self-assessed measures: risk attitude and time horizon. The first is the answer to the question discussed at the end of Section 5.2, the second is the answer to a question on "the horizon considered for planning saving and spending"**.** The regression output (available in the online supplementary appendix), however, does not change in any noticeable way and we omit the two measures from our preferred specification.

Our interpretation of the results relies on the assumption that the heterogeneity in cross-sectional holdings is mainly due to preference heterogeneity rather than transaction costs.

In fact, small and heterogeneous transaction costs may be sufficient to generate infrequent portfolio adjustment, resulting in a large dispersion of portfolio compositions even across households with identical risk preferences. The existing evidence on household trading is mixed. Research on brokerage accounts finds evidence of intense trading activity (e.g., Odean, 1999; Barber and Odean, 2000), while research on retirement plans (e.g., Madrian and Shea, 2001; Agnew et al., 2003), portfolio management (Alessie et al., 2004) and equity market participation (Vissing-Jorgensen, 2002) finds substantial inertia. King and Leape (1998) suggest that there is a significant holding cost (due to transaction and information motives) in the management of a portfolio, which induces investors to hold incomplete and suboptimal portfolios. These costs may surpass the foregone gains that could be obtained with a better structured portfolio.

Direct information on the transaction costs faced by each household is, of course, not available. To some extent we might expect that our proxy variables for financial sophistication also capture part of the heterogeneity in transaction costs faced by the households. Previous research however suggests that transaction costs are less important for wealthier individuals who make more frequent portfolio adjustments. This view is consistent with a fixed element of transaction costs (Agnew et al., 2003; Calvet et al., 2009). Hence, as a robustness check we perform our analysis on the sub-sample of the households whose wealth is in the top 20% of the weighted distribution in our sample. These are more than 20% of the observations in our sample, because the SCF over-samples wealthier households. This sub-sample is remarkably different from the full sample not only because it is richer (and consequently more risk tolerant on average), but also because it includes fewer female heads (14 percent instead of 27 of the whole sample), fewer divorced heads (7 percent instead of 16 percent) and in general more financially sophisticated households. The fourth column of Table 5 shows the estimates for the richest sub-sample in the case of the broad constrained portfolio definition. Despite the different composition of the sub-sample, the signs of the estimated parameters are always consistent with those obtained for the complete set of households, with the most important differences given by the wealth and income elasticity (0.27 and -0.13, respectively) which are sensibly larger than those estimated for the full sample, a stronger age effect and a marginally significant gender effect. As we may expect, in this regression we find lower correlation between our dependent variable and the proxies for financial sophistication and transaction costs: “shopping around for the best rates on credit" is now insignificantly different from zero, and the relative variations for the average household, $\widehat{\Delta \ln\left(1+\gamma_i\right) \Big/ \ln\left(1+\hat{\gamma}_i\right)}$, due to the use of a computer and the number of financial institutions are lower than in the regression based on the whole sample (respectively 16.93 and 2.93 percent rather than 22.75 and 7.10 percent.)

All in all, taking into account the composition effects at work, the qualitative conclusions drawn for the whole sample still hold. This evidence seems to suggest that transaction costs are not affecting our main results significantly.

6. Sensitivity analysis

We are concerned that our findings may change if households take different moments of the asset excess returns. For this reason we check the robustness of our results along three dimensions: *i)* the time series for the numeraire; *ii)* the period coverage of the return time series; *iii)* the time series for real estate returns. In the three cases we estimate RT from the comparison between the (unchanged) household portfolios and the optimal portfolios, which differ from the benchmark case because the implied moment returns of the primitive assets are different. Tables with all the outputs are available in the online supplementary appendix.

6.1. Time series

6.1.1. Numeraire

In the benchmark analysis we compute excess returns as returns net of a risk free asset, which we identify as the return yields to 3-month T-bills. It is however plausible that investors use different numeraires when choosing their portfolio; we consider two cases. First, investors may take a long-run perspective. For this reason, we compute excess returns as returns net of yields from 10-year nominal bonds.[8] Second, less sophisticated investors may choose their portfolio comparing nominal rather than real excess returns. We therefore compute excess returns as the difference between nominal risky returns and real risk free returns, where the latter are derived as nominal 3-month T-bill returns corrected for inflation growth (from CPI index for all urban consumers, all items). In both cases the time se-

[8] Two government bonds in the US have a longer maturity, 20 and 30 years. However, such bonds have not been issued between 2002 and 2004 for the 30-year maturity. Hence, the time series of 10-year bonds is the one with the longest maturity fully covering our sample period.

ries length is 100 observations (from 1980 to 2004 on a quarterly basis), with the first 20 observations for excess returns on real estate imputed as in the benchmark case following Stambaugh (1997).

With these new asset moments we obtain for the optimal portfolio under the broad definition (constructed as in Table 2, panel C) a negative weight on real estate (-39.20 percent) using the 10-year bond numeraire.

6.1.2. Period coverage

Households might estimate the expected asset returns and covariances considering only the nearest past market realizations. Using the benchmark asset time series, we reduce the series length to cover quarterly the period 1990-2004 (60 observations). Since all the time series are available over the whole period, we do not need to correct the moments using the method introduced in Stambaugh (1997).

6.1.3. Real estate returns

Although the features of the MIT-CRE index make this series attractive for our purpose, it is not commonly used to estimate real estate returns. We therefore replicate our benchmark analysis computing real estate returns from an Office of Federal Housing Enterprise Oversight (OFHEO) series.[9] The series is a repeat-sale, purchase-only index calculated for the whole of the US from data provided by Fannie Mae and Freddie Mac (the two biggest mortgage lenders in the US). The series we consider in the analysis covers the same period as in the benchmark (100 quarterly observations from 1980 to 2004). Compared to our benchmark MIT-CRE series, these data are available over the whole sample period (hence no imputation is necessary), but they consider just single-family homes, and ignore earnings from rents. We believe it is important to incorporate rents in our returns, and for this reason we follow Flavin and Yamashita (2002) and Pelizzon and Weber (2008) by adding a constant 5 percent to our returns. The optimal portfolio under broad definition holds a large position in real estate (weight: 71.75 percent) and a negative position in bonds (-12.43 percent).

6.2. Findings

[9] Recently called Federal Housing Finance Agency (FHFA) index.

The first two columns of Table 6 report the results for a representative agent in the economy. The point estimates are lower using the shorter time series, or a different time series for real estate returns. In both cases, real estate returns are less volatile and can be seen as closer to returns of a risk free asset. In all the four cases, the unconstrained (constrained) broad portfolio definition generates the lower (higher) estimate, which ranges between 0.04 and 0.24 (0.25 and 0.44). In all the cases but one (long-run horizon), the expected return gap is lower under the constrained broad portfolio definition, and ranges between 0.30 and 0.55.

Similar findings emerge from the calculation of RT for each household; the median values are reported in the final two columns of Table 6. Figure 4 compares the cdfs of RT estimates (panel A) and expected return gaps (panel B) in the benchmark and four robustness cases under the constrained broad portfolio definition; the figure shows a similar distribution in all the cases. The curves may however hide that households at the lower tail of the RT distribution under the benchmark case, are at the upper tail of the RT distribution under a robustness case. We find that this is not true, as the correlation between benchmark estimates and estimates assuming long-run horizon (nominal returns) is high and equal to 0.98 (0.99). The correlation is smaller, but still high, using a shorter time series (0.65) or the OFHEO series for real estate returns (0.62).

Table 7 reports the output of a regression analysis identical to the benchmark case, where the dependent variable is the logarithm of 1 plus the RT estimate under the constrained broad portfolio definition. To make each column comparable to the third column of Table 5, we normalize the dependent variable to be equal, on average, to the average value under the benchmark case. Overall, the results we found in the benchmark case still hold true here, noticeably the correlations between risk tolerance, age, wealth and the number of financial institutions.

Finally, in a separate analysis, we estimated the RT using the same asset return moments but from a definition of portfolio excluding all the real estate (and related liabilities) that is not residential housing. This exercise is rather different from the previous ones, as it changes the distribution of wealth in our sample. Furthermore, the different portfolio definition implies different constraints on the weights on human capital, bond and real estate holdings. Even so, the estimated RT for the representative agent does not change with respect to the benchmark case, and all the main findings of the regression analysis are confirmed, with the main differences being the relevance of income and the ethnicity. The output of the analysis is reported in the online supplementary appendix.

7. Concluding remarks

In this paper we use household portfolio data from the 2004 US Survey of Consumer Finances to study the distribution of risk preferences in a cross-section of US households. Our measures are deduced from the willingness to bear risk as indicated by the variance of returns of a household's observed portfolio.

Our estimates of the preference parameter show substantial heterogeneity across individuals. In our preferred case, we find risk tolerance to correlate negatively with age, and positively with wealth and financial sophistication. The correlation between risk tolerance and age is instead not significant if we restrict our attention to financial portfolios and ignore constraints. A sensitivity analysis confirms these results, and suggests that education, gender, race and household size have no relation with the household's risk attitude.

The present research has at least two limitations that should be kept in mind when interpreting the results. We group our assets in few categories. Doing so, we neglect the tax differentials of all instruments. This means in particular that we ignore that loan interests are tax deductible, and that capital gains from real estate after three years and imputed rents are tax free. We also ignore the tax advantages related to bonds and stocks, which depend on the specific investment channel (directly held assets or assets held through a fund). With this respect we can conjecture that as the main effect of the differential tax treatment is to make real estate investment and indebtedness more valuable, we are currently overestimating the risk tolerance of those households with high debt and high investments in real estate. A second limitation has to do with the potential stickiness in portfolio choice brought by unobserved transaction costs, minimum investment requirements and other market imperfections. Although we cannot control for it, a robustness check run on a subsample of the wealthiest households – for which such costs should be less relevant – makes us confident that our analysis is still able to provide useful insights on the risk tolerance heterogeneity.

There are at least two main directions for future research. The analysis deserves further efforts in order to better understand the role played by transaction costs and to investigate the causality relations between risk preference, wealth and observable characteristics. Using repeated cross-sections of the SCF may help to better disentangle wealth and age effects. From the theoretical point of view it is then interesting to evaluate the possibility to apply our approach in a multi-period framework, closer to a life-cycle model of asset allocation. This will allow us to disentangle risk aversion from the investor's planning horizon length.

A. Appendix

A.1. Risk tolerance and certain equivalent return

In the mean-variance model of Markowitz (1952), an investor i with given risk tolerance $\gamma_i \geq 0$ optimizes the trade-off between the mean and the variance of portfolio returns. The agent chooses the portfolio $w_i(\gamma_i) = \left[w_{i,1}(\gamma_i) \quad w_{i,2}(\gamma_i) \quad \dots \quad w_{i,n}(\gamma_i) \right]'$ such that

$$(13) \qquad w_i(\gamma_i) = \arg\max_x \left\{ x'e + r_0 - \frac{1}{2\gamma_i} x'Sx \right\}$$

possibly subject to constraints (6) and (7) on portfolio composition, with r_0 rate of return on the risk free asset, and (e, S) estimates of the assets' expected returns and covariances. The objective function (13) is known as the Certainty Equivalent Return (CER) for the expected utility of a mean-variance estimator, and also approximates the CER of a myopic investor with quadratic utility functions.

For each household we observe a portfolio of weights $\omega_i = \left[\omega_{i,1} \quad \omega_{i,2} \quad \dots \quad \omega_{i,n} \right]'$. It is common practice in this literature to evaluate the efficiency of the observed portfolio from the comparison between the CERs of observed and optimal portfolios (see, e.g., DeMiguel et al., 2009). Define the distance between the two CERs as:

$$(14) \qquad \Delta(\gamma_i) = \left(w_i'(\gamma_i) e - \frac{1}{2\gamma_i} w_i'(\gamma_i) S w_i(\gamma_i) \right) - \left(\omega_i' e - \frac{1}{2\gamma_i} \omega_i' S \omega_i \right) \geq 0.$$

Our measure of implicit risk tolerance is the value of γ_i that minimizes $\Delta(\gamma_i)$,

$$(15) \qquad \hat{\gamma}_i = \arg\min_{\gamma_i} \left\{ \Delta(\gamma_i) \right\}$$

and the expected return gap $\rho_i = \Delta(\hat{\gamma}_i)$ is the minimized objective function.

The first order condition of the problem in equation (15) is

$$(16) \qquad w_i(\gamma_i)' S w_i(\gamma_i) = \omega_i' S \omega_i$$

and requires that the risk associated to efficient and observed portfolios is the same. This requirement coincides with equation (1).

A.2. Portfolio construction

The SCF is exceptionally good in providing detailed information on primitive and composite assets. For instance with regards to mutual funds, we know whether they are tax-free, bond, balanced, stock or other funds and can then group them accordingly. For four assets (IRA-Keogh accounts, retirement accounts, annuities, and trust-managed accounts) we know how they are invested, and classify 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. 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. 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.

In constructing portfolios we make two arbitrary assumptions. We assume that balanced and other mutual 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 (see Table 1). More substantively, our broad definition of portfolio needs an imputation of human capital.

Human Capital (HC) is calculated as the sum of the present value of current and future household earnings, including pension payments. In principle, for each household in the sample we would like to know current and future earnings, as well as retirement age and survival probabilities. This would produce the best possible estimate. Unfortunately, the SCF provides us only information on current earnings.

The approach we follow is to exogenously set retirement age at 65 and survival probabilities to the 2004 period life tables available from Human Mortality Database, and use the (education-specific) earnings profile estimated in Cocco et al. (2005)[10] to project up to the retirement age the current values reported by SCF respondents. After retirement, the replacement rate estimated in Cocco et al. (2005) from the same data determines the first pension payment. Further payments are assumed to be constant in real terms. The earnings projections are then multiplied by the relevant (age- and gender- specific) survival probabilities, and discounted at the real risk-free rate to get a household-specific estimate of HC. We estimate the real risk-free rate as 1.954%, as the ratio between the nominal risk free rate in our sample and seasonally-adjusted inflation (CPI, all urban consumers, all items) over the same period.

Let us consider a household i of age t. From the SCF we compute its total income $y_{i,t}$, which we define as the sum of (before taxes) family income from wages and salaries, from business, unemployment compensation, workers compensation, Social Security, supplemental Social Security, child support, other welfare and assistance programs, and total transfers (mainly help from relatives).[11] From the survey we also know the head's gender G_i and education X_i (which we group in three categories: less than high school, high school, college), and whether the head is retired. Using this information, we compute human capital as follows:

- for households with retired head, or head above the retirement age *R*:

(17)
$$HC_{i,t} = \sum_{s=t}^{D} \frac{y_{i,t}\pi_{t,s}\left(G_i\right)}{\left(1+r\right)^{s-t}}$$

- for households with working head below the retirement age *R*:

(18)
$$HC_{i,t} = \sum_{s=t}^{R} \frac{y_{i,t}\left(1+g_s\left(X_i\right)\right)\pi_{t,s}\left(G_i\right)}{\left(1+r\right)^{s-t}} + \sum_{s=R+1}^{D} \frac{\alpha\left(X_i\right)y_t\left(1+g_R\left(X_i\right)\right)\pi_{t,s}\left(G_i\right)}{\left(1+r\right)^{s-t}}$$

where $\pi_{t,s}\left(G_i\right)$ is the probability of a household head with gender G_i and aged t to be alive at age s, r is the real risk-free rate, $g_s\left(X_i\right)$ is the income growth at age s condition-

[10] The authors estimate the earnings profile from the US Panel Study of Income Dynamics as a third-order polynomial on age of the head, controlling for family size, marital status, and education. In their sample they consider only households whose head is working, male, and aged between 20 and 65.

[11] Consistently with Cocco et al. (2005). This definition of labor income is broad to implicitly allow for (potentially endogenous) ways of self-ensuring against pure labor income risk. A narrower definition would overstate the risk that agents actually face.

al on education X_i, and $\alpha(X_i)$ is the replacement rate at retirement, conditional on education X_i. Table 8 summarizes our calibration of the exogenous parameters.

This crude construction of human capital is admittedly arbitrary. Ideally, we would calculate human capital separately for the head and the spouse, and then combine the two to form the household human capital. This would require us to take into account survival pensions, and predict the age-evolution of income at the individual level. However, such measure is heavily affected by (unpredictable) family dynamics. For this reason, the literature usually estimates the age-profile of household income, which happens to be more stable over the life-cycle (see, e.g., Cocco et al., 2005; Scholz et al., 2006). We therefore take the household as analysis unit, and compute human capital using the age-evolution of household income.

References

Agnew, J., P. Balduzzi, and **A. Sundén** (2003), "Portfolio Choice and Trading in a Large 401(k) Plan", *American Economic Review*, Vol. 93(1), pp. 193-205.

Alessie, R., S. Hochguertel, and **A. Van Soest** (2004), "Ownership of Stocks and Mutual Funds: a Panel Data Analysis", *Review of Economics and Statistics*, Vol. 86(3), pp. 783-796.

Attanasio, O., and **G. Weber** (1995), "Consumption over the Life-Cycle and over the Business Cycle", *American Economic Review*, Vol. 85(5), pp. 1118-1137.

Barber, B.M., and **T. Odean** (2000), "Trading is Hazardous to Your Wealth: the Common Stock Investment Performance of Individual Investors", *Journal of Finance*, Vol. 55(2), pp. 773-806.

Barsky, R.B., F.T. Juster, M.S. Kimball, and **M.S. Shapiro** (1997), "Preference Parameters and Behavioral Heterogeneity: an Experimental Approach in the Health and Retirement Study", *Quarterly Journal of Economics*, Vol. 112(2), pp. 537-579.

Beetsma, R.M.W.J., and **P.C. Schotman** (2001), "Measuring Risk Attitudes in a Natural Experiment: Data from the Television Show LINGO", *Economic Journal*, Vol. 111(474), pp. 821-848.

Ben Mansour, S., A. Jouini, **J.M. Marin**, **C. Napp**, and **C. Robert** (2008), "Are Risk Averse Agent More Optimistic? A Bayesian Estimation Approach", *Journal of Applied Econometrics,* Vol. 23(6), pp. 843-860.

Blundell, R., R. Browning, and **C. Meghir** (1994), "Consumer Demand and the Life-Cycle Allocation of Household Expenditures", *Review of Economic Studies*, Vol. 61(1), pp. 57-80.

Calvet, L.E., J.Y. Campbell, and **P. Sodini** (2009), "Fight or Flight? Portfolio Rebalancing by Individual Investors", *Quarterly Journal of Economics*, Vol. 124(1), pp. 301-348.

Campbell, J.Y. (2003), "Consumption-Based Asset Pricing", Chapter 13 in G. Constantinides, M. Harris, and R. Stulz (eds.) *Handbook of the Economics of Finance*, Vol. IB, North-Holland, Amsterdam, Netherlands.

Campbell, J.Y. (2006), "Household Finance", *Journal of Finance,* Vol. 61(4), pp. 1553-1604.

Chetty, **R.** (2006), "A New Method of Estimating Risk Aversion", *American Economic Review*, Vol. 96(5), pp. 1821-1834.

Choi, **S.**, **R. Fisman, D. Gale** and **S. Kariv** (2007), "Consistency and Heterogeneity of Individual Behavior under Uncertainty", *American Economic Review*, Vol. 97(5), pp. 1921-1938.

Chopra, V.K., and **W.T. Ziemba** (1993), "The Effect of Errors in Means, Variances, and Covariances on Optimal Portfolio Choice", *Journal of Portfolio Management*, Vol. 19(1), pp. 6-11.

Cocco, **J.F.** (2005), "Portfolio Choice in the Presence of Housing", *Review of Financial Studies*, Vol. 18(2), pp. 535-567.

Cocco, J., F. Gomes, and **P. Maenhout** (2005), "Consumption and Portfolio Choice over the Life-Cycle", *Review of Financial Studies*, Vol. 18(2), pp. 491-533.

Cohen, A., and **L. Einav** (2007), "Estimating Risk Preferences from Deductible Choices", *American Economic Review*, Vol. 97(3), pp. 745-788.

Cohn, **R.A., W.G. Lewellen**, **R.C. Lease**, and **G.G. Schlarbaum** (1975), "Individual Investor Risk Aversion and Investment Portfolio Composition", *Journal of Finance*, Vol. 30(2), pp. 605-620.

Croson, **R.,** and **U. Gneezy** (2008), "Gender Differences in Preferences", *Journal of Economic Literature*, Vol. 47(2), pp. 1-27.

DeMiguel, **V.**, **L. Garlappi**, and **R. Uppal** (2009), "Optimal versus naïve diversification: how inefficient is the 1/N portfolio strategy?", *Review of Financial Studies*, Vol. 22(5), pp. 1915-1953.

Donkers, **B., B. Melenberg**, and **A. van Soest** (2001), "Estimating Risk Attitudes Using Lotteries: a Large Sample Approach", *Journal of Risk and Uncertainty*, Vol. 22(2), pp. 165-195.

Figlewski, **S.** (1981), "The Informational Effects of Restrictions on Short Sales: Some Empirical Evidence", *Journal of Financial and Quantitative Analysis*, Vol. 16(4), pp. 463-476.

Fisher, **J., D. Geltner**, and **H. Pollakowski** (2007), "A Quarterly Transaction-Based Index (TBI) of Institutional Real Estate Investment Performance and Movements in Supply and Demand", *Journal of Real Estate Finance and Economics*, Vol. 34(1), pp. 5-33.

Flavin, **M.,** and **T. Yamashita** (2002), "Owner-Occupied Housing and the Composition of the Household Portfolio", *American Economic Review*, Vol. 92(1), pp. 345-362.

Friedman, **B.** (1974), "Risk Aversion and the Consumer Choice of Health Insurance Option", *Review of Economics and Statistics*, Vol. 56(2), pp. 209-214.

Friend, **I.,** and **M.E. Blume** (1975), "The Demand for Risky Assets", *American Economic Review*, Vol. 65(5), pp. 900-922.

Green, **R.C.,** and **B. Hollifield** (1992), "When Will Mean-Variance Efficient Portfolios be Well Diversified?", *Journal of Finance*, Vol. 47(5), pp. 1785-1809.

Guiso, **L.,** and **T. Jappelli** (2005), "Household Portfolio Choice and Diversification Strategies", Trends in Saving and Wealth Working Paper No. 7/05.

Guiso, **L.,** and **M. Paiella** (2008), "Risk Aversion, Wealth and Background Risk", *Journal of the European Economic Association*, Vol. 6(6), pp. 1109-1150.

Guiso, **L., M. Haliassos,** and **T. Jappelli** (2001), *Household Portfolios*, MIT Press, Cambridge, MA.

Halek, **M.,** and **J.G. Eisenhauer** (2001), "Demography of Risk Aversion", *Journal of Risk and Insurance*, Vol. 68(1), pp. 1-24.

Hansen, **L.P.,** and **K.J. Singleton** (1983), "Stochastic Consumption, Risk Aversion and the Temporal Behavior of Stock Returns", *Journal of Political Economy*, Vol. 91(2), pp. 249-265.

Kimball, **M.S., C.R. Sahm,** and **M.D. Shapiro** (2008), "Imputing Risk Tolerance from Survey Responses", *Journal of the American Statistical Association*, Vol. 103(483), pp. 1028-1038.

King, **M.A,** and **J.I. Leape** (1998), "Wealth and Portfolio Composition: Theory and Evidence", *Journal of Public Economics*, Vol. 69(2), pp. 155-193.

Madrian, B., and **D. Shea** (2001), "The Power of Suggestion: Inertia in 401(k) Participation and Savings Behavior", *Quarterly Journal of Economics*, Vol. 116(4), pp. 1149-1188.

Markowitz, **H.M.** (1952), "Portfolio Selection", *Journal of Finance*, Vol. 7(1), pp. 77-91.

McInish, **T.H.** (1982), "Individual Investors and Risk-taking", *Journal of Economic Psychology*, Vol. 2(2), pp. 125-136.

Mehra, **R.,** and **E. Prescott** (1985), "The Equity Premium: a Puzzle", *Journal of Monetary Economics*, Vol. 15(2), pp. 145-161.

Merton, **R.C.** (1980), "On Estimating the Expected Return on the Market: an Exploratory Investigation", *Journal of Financial Economics*, Vol. 8(4), pp. 323-361.

Morin, **R.A.,** and **A.F. Suarez** (1983), "Risk Aversion Revisited", *Journal of Finance*, Vol. 38(4), pp. 1201-1216.

Odean, **T.** (1999), "Do Investors Trade Too Much?", *American Economic Review*, Vol. 89(5), pp. 1279-1298.

Palsson, **A.M.** (1996), "Does the Degree of Risk Aversion Vary with Household Characteristics?", *Journal of Economic Psychology*, Vol. 17(6), pp. 771-787.

Pelizzon, **L.,** and **G. Weber** (2008), "Are Household Portfolios Efficient? An Analysis Conditional on Housing", *Journal of Financial and Quantitative Analysis*, Vol.43(2), pp. 401-432.

Pelizzon, **L.,** and **G. Weber** (2009), "Efficient Portfolios when Housing Needs Change over the Life-Cycle", *Journal of Banking and Finance*, Vol. 33(11), pp. 2110-2121.

Riley, **W.B.,** and **K.V. Chow** (1992), "Asset Allocation and Individual Risk Aversion", *Financial Analysts Journal*, Vol. 48(6), pp. 32-37.

Rubin, D.B. (1987), *Multiple Imputations for Nonresponse in Surveys*, Wiley, New York, NY.

Sahm, **C.** (2007), "How Much Does Risk Tolerance Change?", Finance and Economics Discussion Series No. 2007-66, Federal Reserve Board.

Scholz, J.K., A. Seshadri, and **S. Khitatrakun** (2006), "Are Americans Saving "Optimally" for Retirement?", *Journal of Political Economy*, Vol. 114(4), pp. 607-643.

Schubert, **R., M. Brown**, **M. Gysler**, and **H.W. Brachinger** (1999), "Financial Decision-Making: Are Women Really More Risk-Averse?", *American Economic Review*, Vol. 89(2), pp. 381-385.

Shaw, **K.L.** (1996), "An Empirical Analysis of Risk Aversion and Income Growth", *Journal of Labor Economics*, Vol. 14(4), pp. 626-653.

Siegel, **F.W.,** and **J.P. Hoban** (1982), "Relative Risk Aversion Revisited", *Review of Economics and Statistics*, Vol. 64(3), pp. 481-487.

Stambaugh, **R.F.** (1997), "Analyzing Investments whose Histories Differ in Length", *Journal of Financial Economics*, Vol. 45(3), pp. 285-331.

Szpiro, **G.G.** (1986), "Measuring Risk Aversion: an Alternative Approach", *Review of Economics and Statistics*, Vol. 68(1), pp. 156-159.

Vissing-Jorgensen, **A.** (2002), "Towards an Explanation of Household Portfolio Choice Heterogeneity: Non-financial Income and Participation Cost Structures", NBER Working Paper No. 8884.

Wasserman, L. (2006), *All of Nonparametric Statistics*, Springer, New York, NY.

Table 1. Aggregate wealth and portfolio composition (% from SCF 2004)

Category	Definition	
	Narrow	Broad
Wealth (USD)		
25th percentile	1,538	70,463
50th percentile	11,000	141,300
75th percentile	59,000	256,692
Mean	169,484	475,687
Portfolio composition		
Checking accounts	5.388	1.918
Savings and money market accounts	8.766	3.120
Call accounts at brokerages	1.255	0.447
IRA-KEOGH accounts	2.270	0.808
Retirement accounts	0.803	0.286
Annuities	0.914	0.326
Trust-managed accounts	1.360	0.484
DEPOSITS	**20.756**	**7.388**
Certificates of deposits	4.326	1.540
Savings bonds	0.655	0.233
Directly held corp. bonds	6.116	2.177
Tax free mutual funds	1.694	0.603
Govt. bond mutual funds	0.520	0.185
Other bond mutual funds	1.060	0.377
½ Balanced mutual funds	0.640	0.228
½ Other mutual funds	0.559	0.199
IRA-KEOGH accounts	5.805	2.066
Retirement accounts	0.800	0.285
Annuities	0.874	0.311
Trust-managed accounts	1.734	0.617
Life insurances (cash value)	3.450	1.228
Mortgages on primary residence (-)	-	-11.100
Lines of credit on primary residence (-)	-	-0.350
Loans on other real estate (-)	-	-2.717
BONDS	**28.231**	**-4.119**
Directly held stocks	20.670	7.357
Stock mutual funds	11.531	4.104
½ Balanced mutual funds	0.640	0.228
½ Other mutual funds	0.559	0.199
IRA-KEOGH accounts	11.311	4.026
Retirement accounts	1.899	0.676
Annuities	1.294	0.460
Trust-managed accounts	3.109	1.106
STOCKS	**51.013**	**18.156**
Owner-occupied primary residence	-	38.574
Other real estate	-	13.725
REAL ESTATE	**-**	**52.299**
HUMAN CAPITAL	**-**	**26.276**

Number of observations: 4,095.

Table 2. Excess return time series statistics

Panel A. Historical excess returns (%)

Asset category	Bond	Stock	Real estate	Human capital
Mean	3.730	5.319	2.286	0.401
Std. deviation	8.719	17.624	7.878	2.492
Sharpe ratio	42.775	30.182	29.018	16.074

Risk free historical return: 5.932 percent.

Panel B. Covariances and correlations (%)

Asset category	Bond	Stock	Real estate	Human capital
Bond	0.760	*26.743*	*25.859*	*15.316*
Stocks	0.411	3.106	*30.605*	*16.668*
Real estate	0.178	0.425	0.621	*46.083*
Human capital	0.033	0.073	0.091	0.062

Correlations in Italic.

Panel C. Optimal portfolios (%)

Portfolio def.	Bond	Stock	Real estate	Human capital
Narrow	78.914	21.086	-	-
Broad	45.004	10.517	18.203	26.276

Narrow definition: tangency portfolio. Broad definition: efficient portfolio with equality constraint on the human capital weight, and weights on risky assets summing to one.

Table 3. Summary statistics

Portfolio def.	Representative agent		Household-specific (median)	
	Risk tolerance	Expected return gap (%)	Risk tolerance	Expected return gap (%)
Narrow, unconstrained	0.211 (0.203, 0.219)	0.903 (0.817, 0.991)	0.080 (0, 0.345)	0.116 (0, 2.669)
Broad, unconstrained	0.124 (0.122, 0.127)	0.888 (0.843, 0.935)	0.115 (0.022, 0.286)	0.992 (0.080, 7.389)
Broad, constrained	0.368 (0.346, 0.390)	0.500 (0.468, 0.535)	0.142 (0.008, 0.933)	0.044 (0, 1.357)

In parentheses: Representative agent: 95% confidence interval based on 1,000 bootstrap simulations over the household units. From each simulation we compute the aggregate portfolio using the sampling weights, and separately for the five imputations; Household-specific: 2.5 and 97.5% quantiles of the empirical distribution.

Table 4. Implicit median risk tolerance (RT) and self-assessed risk attitude

	Narrow def., unconstrained	Broad def., unconstrained	Broad def., constrained	N. obs.
Self-assessed risk tolerant	**0.165**	**0.130**	**0.288**	**1,066**
Age class				
35 or below	0.114	0.105	0.214	184
36 – 50	0.154	0.128	0.276	419
51 – 65	0.216	0.140	0.372	340
66 or above	0.191	0.138	0.295	123
Wealth class				
I quartile	0	0.023	0.009	134
II quartile	0.127	0.129	0.279	135
III quartile	0.172	0.136	0.323	163
IV quartile	0.227	0.143	0.414	634
Self-assessed risk averse	**0.058**	**0.112**	**0.117**	**3,029**
Age class				
35 or below	0	0.039	0.031	525
36 – 50	0.039	0.115	0.175	895
51 – 65	0.116	0.115	0.154	927
66 or above	0.089	0.117	0.081	682
Wealth class				
I quartile	0	0.023	0.009	716
II quartile	0.014	0.120	0.178	580
III quartile	0.097	0.119	0.151	554
IV quartile	0.179	0.135	0.266	1,179
Whole sample	**0.080**	**0.115**	**0.142**	**4,095**

Table 5. Heterogeneity of risk tolerance

	Narrow def., unconstrained	Broad def., unconstrained	Broad def., constrained	
			Whole sample	Top 20% wealth
Age/100	-2.206	-5.604***	-17.454***	-40.187***
	(1.389)	(1.072)	(5.076)	(11.607)
Ln(income)/10	-5.477**	-14.896***	-5.139	-36.467**
	(2.274)	(1.722)	(7.968)	(15.541)
Ln(wealth)/10	22.390***	16.156***	29.872***	72.741***
	(0.744)	(0.620)	(2.843)	(13.505)
With children	-0.054	0.360	-1.258	-2.565
	(0.350)	(0.250)	(1.460)	(2.150)
Female	0.085	-0.023	-4.428	-7.217*
	(0.521)	(0.508)	(3.689)	(4.245)
Divorced	0.618	1.073**	8.792***	0.886
	(0.556)	(0.455)	(2.923)	(3.560)
Widowed	-0.025	0.432	7.253	3.834
	(0.765)	(0.674)	(5.312)	(5.462)
Never married	0.327	-0.951*	3.514	-.2.048
	(0.582)	(0.529)	(3.385)	(5.544)
Non-white	-0.689*	0.077	-0.328	-2.139
	(0.379)	(0.307)	(1.748)	(3.014)
High school graduate	0.195	-0.309	0.756	-3.211
	(0.864)	(0.749)	(2.168)	(12.650)
College graduate	0.948	-0.056	3.104	1.995
	(0.879)	(0.797)	(2.846)	(12.601)
Employed	-0.283	0.546	0.590	-3.208
	(0.478)	(0.338)	(1.398)	(3.070)
Self-employed	-0.822	0.012	2.849	-2.686
	(0.597)	(0.386)	(2.935)	(3.229)
With financial advisor	0.268	-0.005	0.279	0.228
	(0.337)	(0.218)	(1.334)	(1.804)
Works in finance sector	0.747	-0.482	3.238	2.362
	(0.575)	(0.381)	(3.014)	(3.495)
Shops around	0.790**	0.470**	3.546**	0.850
for best rates on credit	(0.320)	(0.235)	(1.395)	(1.982)
Uses a computer	0.592	0.258	4.867**	5.366**
to manage money	(0.410)	(0.275)	(1.972)	(2.161)
N. financial institutions	0.239***	0.214***	1.524***	0.930**
where doing business	(0.066)	(0.044)	(0.357)	(0.425)
Self-assessed good health	-0.219	0.330	2.999*	0.937
	(0.357)	(0.258)	(1.608)	(2.081)
Optimistic about future	0.512	0.120	0.599	0.687
	(0.310)	(0.230)	(1.427)	(1.849)
Constant	-6.311***	10.298***	-9.652	-8.111
	(2.369)	(1.881)	(8.196)	(24.968)
Observations	4095	4095	4095	1602
Mult. imp. minimum dof	89.0	146.8	122.3	92.4
RT (γ) average household	0.101	0.113	0.239	0.373

The dependent variable is $\ln(1+\gamma)$*; all parameters and standard errors are multiplied by 100.*

Robust standard errors in parentheses. Method: OLS.

" RT (γ) *average household" is computed as* $\exp\left\{\overline{\ln(1+\gamma)}\right\}-1$ *where* $\overline{\ln(1+\gamma)}$ *is the sample average.*

****: significantly different from 0 at 1 percent; **: at 5 percent; *: at 10 percent.*

Table 6. Summary statistics, robustness check

Portfolio def.	Representative agent		Household-specific (median)	
	Risk tolerance	Expected return gap (%)	Risk tolerance	Expected return gap (%)
Numeraire: long-run horizon				
Narrow, unconstrained	0.385 (0.370, 0.399)	0.324 (0.289, 0.360)	0.140 (0, 0.632)	0.073 (0, 1.070)
Broad, unconstrained	0.236 (0.231, 0.241)	1.109 (1.065, 1.153)	0.216 (0.045, 0.540)	1.211 (0.215, 5.830)
Broad, constrained	0.439 (0.418, 0.459)	0.414 (0.382, 0.450)	0.217 (0.003, 0.976)	0.026 (0.000, 1.445)
Numeraire: nominal returns				
Narrow, unconstrained	0.161 (0.154, 0.166)	1.406 (1.281, 1.535)	0.059 (0, 0.264)	0.136 (0, 3.926)
Broad, unconstrained	0.082 (0.080, 0.084)	1.139 (1.083, 1.198)	0.075 (0.010, 0.201)	1.163 (0.078, 9.592)
Broad, constrained	0.384 (0.363, 0.404)	0.546 (0.513, 0.586)	0.158 (0.001, 0.943)	0.068 (0.000, 1.384)
Shorter time series				
Narrow, unconstrained	0.105 (0.100, 0.109)	3.117 (2.879, 3.360)	0.031 (0, 0.188)	0.254 (0, 7.557)
Broad, unconstrained	0.056 (0.055, 0.058)	1.935 (1.853, 2.024)	0.051 (0.006, 0.133)	1.779 (0.053, 9.853)
Broad, constrained	0.350 (0.336, 0.361)	0.324 (0.299, 0.355)	0.122 (0.003, 0.726)	0.068 (0.000, 0.898)
Real estate returns: OFHEO series				
Narrow, unconstrained	0.211 (0.203, 0.219)	0.903 (0.817, 0.991)	0.080 (0, 0.345)	0.116 (0, 2.669)
Broad, unconstrained	0.041 (0.040, 0.043)	0.875 (0.750, 1.011)	0.036 (0.016, 0.112)	0.540 (0.023, 8.469)
Broad, constrained	0.254 (0.225, 0.281)	0.296 (0.273, 0.321)	0.087 (0.008, 0.922)	0.072 (0, 0.934)

In parentheses: Representative agent, 95% confidence interval based on 1,000 bootstrap simulations over the household units. From each simulation we compute the aggregate portfolio using the sampling weights, and separately for the five imputations; Household-specific: 2.5 and 97.5% quantiles of the empirical distribution.

Table 7. Heterogeneity of risk tolerance, robustness check

	Numeraire		Shorter	OFHEO series
	Long-run horizon	**Nominal returns**	**time series**	**for real estate**
Age/100	-15.757***	-18.969***	-18.304***	-11.087***
	(4.733)	(4.820)	(3.392)	(3.680)
Ln(income)/10	-3.982	-2.427	-10.670*	-9.224*
	(7.213)	(7.638)	(5.899)	(5.351)
Ln(wealth)/10	27.741***	30.618***	39.016***	22.597***
	(2.615)	(2.684)	(1.878)	(2.061)
With children	-1.408	-1.311	-2.346***	-2.571***
	(1.347)	(1.361)	(0.822)	(0.813)
Female	-4.515	-3.984	-2.376***	-2.430
	(3.391)	(3.432)	(1.800)	(1.789)
Divorced	7.742***	8.454***	4.857	3.671**
	(2.686)	(2.718)	(1.529)	(1.468)
Widowed	7.009	6.618	2.110	3.335
	(4.901)	(4.966)	(2.750)	(2.475)
Never married	3.486	2.998	0.469	1.955
	(3.194)	(3.147)	(1.729)	(1.908)
Non-white	0.561	-0.542	-0.601	-1.410
	(1.674)	(1.619)	(0.912)	(0.931)
High school graduate	0.961	1.210	0.298	1.430
	(2.061)	(2.113)	(1.850)	(1.420)
College graduate	3.185	3.634	4.031*	4.458***
	(2.671)	(2.729)	(2.074)	(1.646)
Employed	0.411	0.667	-0.083	-1.136
	(1.259)	(1.356)	(1.158)	(1.315)
Self-employed	1.590	2.849	1.785	-0.425
	(2.384)	(2.746)	(1.545)	(1.559)
With financial advisor	0.236	0.464	1.561*	1.193
	(1.231)	(1.254)	(0.807)	(0.791)
Works in finance sector	3.320	2.687	1.105	0.177
	(2.903)	(2.751)	(1.281)	(1.062)
Shops around	2.788**	3.415***	1.864**	1.601**
for best rates on credit	(1.259)	(1.301)	(0.778)	(0.786)
Uses a computer	4.588**	4.556**	3.325***	3.401***
to manage money	(1.900)	(1.818)	(0.999)	(0.900)
N. financial institutions	1.408***	1.517***	1.246***	1.112***
where doing business	(0.339)	(0.330)	(0.194)	(0.224)
Self-assessed good health	2.706*	2.696*	1.332	1.118
	(1.511)	(1.492)	(0.867)	(0.877)
Optimistic about future	0.384	0.536	0.698	1.322*
	(1.334)	(1.332)	(0.785)	(0.794)
Constant	-8.246	-12.719	-9.262	-1.378
	(7.635)	(7.792)	(5.882)	(5.776)
Observations	4095	4095	4095	4095
Mult. imp. minimum dof	166.5	90.9	58.5	27.2
RT (γ) average household	0.292	0.238	0.172	0.171

Based on the broad definition, constrained (whole sample).
The dependent variable is $\ln(1+\gamma)$, *and is normalized to produce the same RT for the average household as the benchmark case. All parameters and standard errors are multiplied by 100.*
Robust standard errors in parentheses. Method: OLS.
" RT (γ) *average household" is computed as* $\exp\left\{\overline{\ln(1+\gamma)}\right\}-1$ *where* $\overline{\ln(1+\gamma)}$ *is the sample average.*
****: significantly different from 0 at 1 percent; **: at 5 percent; *: at 10 percent.*

Table 8. Parameter used in the human capital imputation

Symbol	Definition	Calibration
D	Maximum death age	100
R	Retirement age	65
$\pi_{t,s}(G_i)$	Probability of being alive at age s conditional on being alive at age t, for given gender G_i	Human Mortality Database period life tables for year 2004, males and females
r	Discount rate	Nominal risk free rate (3-month T-bills) net of inflation (CPI, all items), period: 1980-2004 =1.954%
$g_s(X_i)$	Income growth rate, for given education X_i	Cocco et al. (2005)
$\alpha(X_i)$	Replacement rate, for given education X_i	Cocco et al. (2005)

Figure 1. Metric used for RT estimation

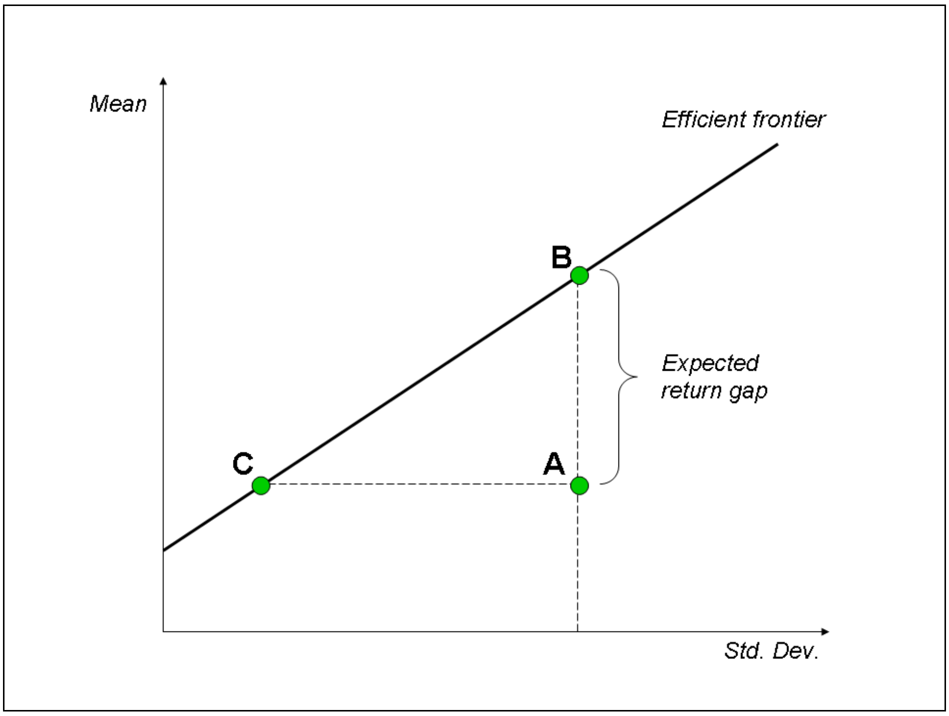
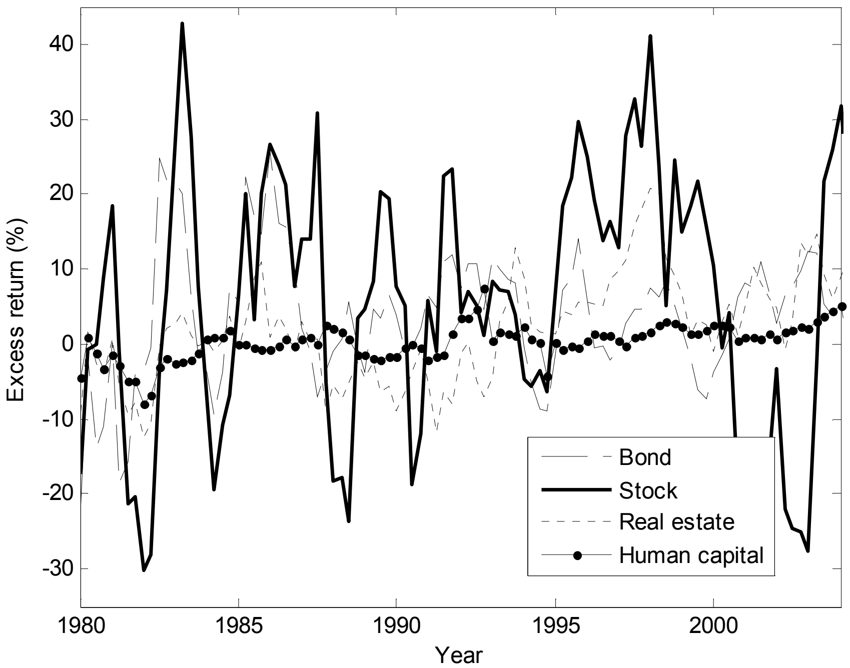


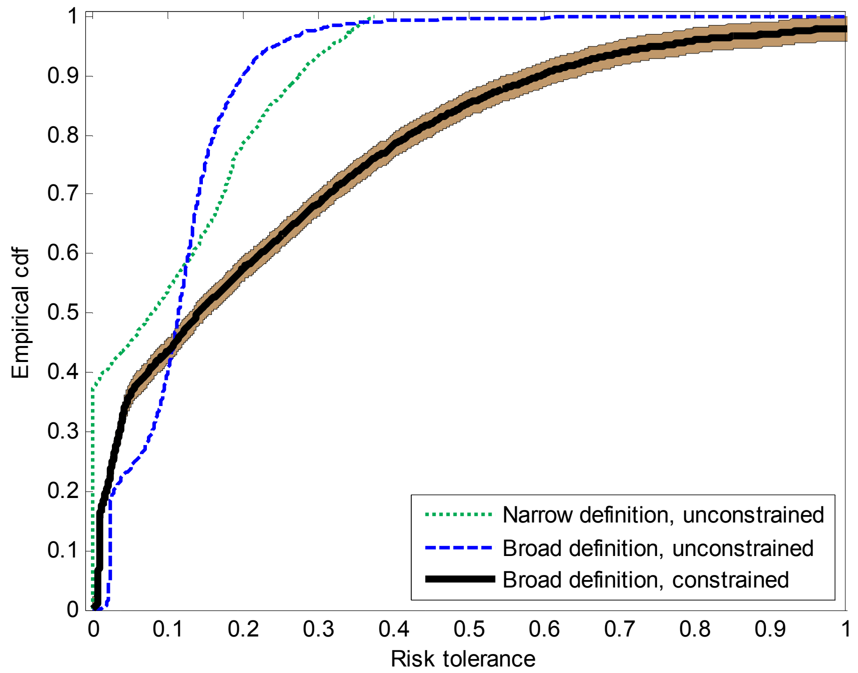
Figure 2. Historical excess returns, 1980-2004



Note: real estate returns before 1985 are imputed according to Stambaugh (1997).

Figure 3. Empirical cumulative distributions

Panel A. Risk tolerance



Panel B. Expected return gap

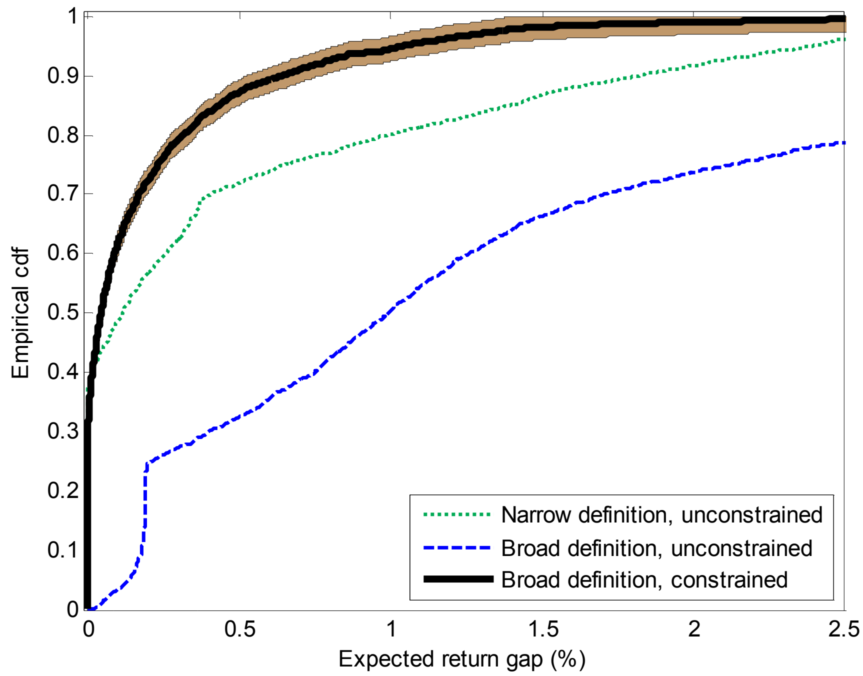
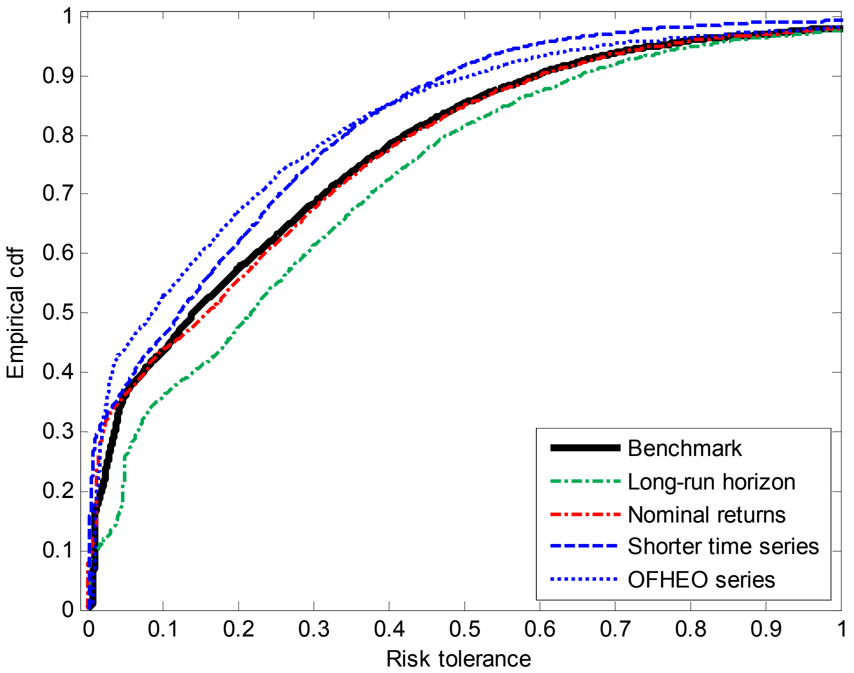
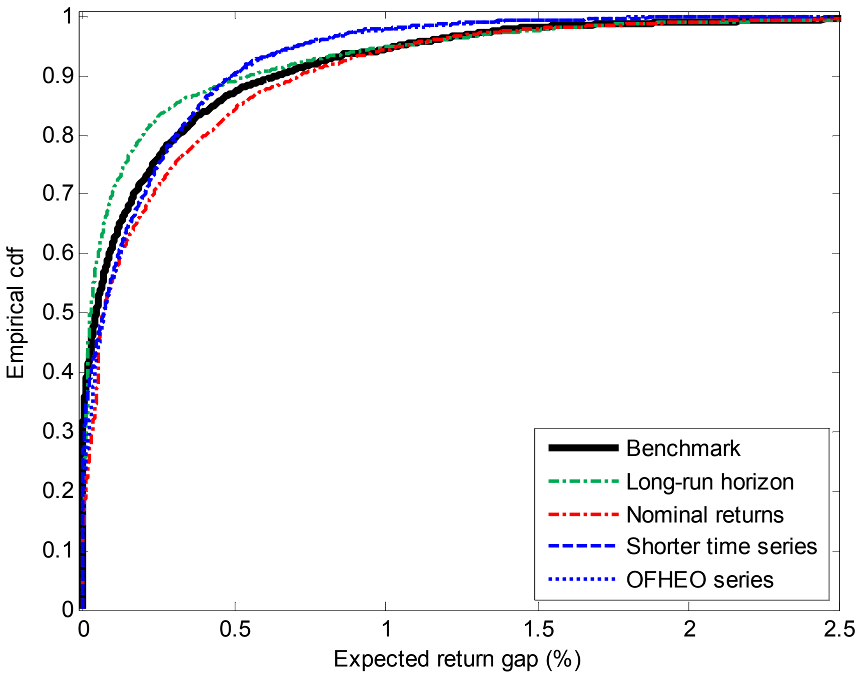


Figure 4. Empirical cumulative distributions, robustness check

Panel A. Risk tolerance



Panel B. Expected return gap



HOUSEHOLD PORTFOLIOS AND IMPLICIT RISK PREFERENCE

ALESSANDRO BUCCIOL
University of Verona, University of Amsterdam, and Netspar

RAFFAELE MINIACI
University of Brescia

Supplementary Appendix

– NOT FOR PUBLICATION –

S.1. Specification with self-assessed measures

In this exercise we use the benchmark estimates of risk tolerance and replicate the regression analysis of Table 5 in the main text, with a richer specification that includes two self-assessed measures on risk attitude and time horizon.

The first measure is based on the SCF 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?»
>
> 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

where we code as "self-assessed risk tolerant" households responding 1 or 2.

The second measure is based on the SCF question:

> «In planning (your/your family's) saving and spending, which of the following is most important to [you/you and your (husband/wife/partner)]: the next few months, the next year, the next few years, the next 5 to 10 years, or longer than 10 years? »
>
> 1. Next few months
> 2. Next year
> 3. Next few years
> 4. Next 5-10 years
> 5. Longer than 10 years

where we code as "self-assessed short-horizon planner" households responding 1 or 2.

Results from this analysis are shown in Table S1.

S.2. Results using different asset moments

In this exercise we estimate risk tolerance for each household, taking the same definition of portfolio as in the benchmark case but changing the asset returns.

S.2.1. Numeraire

We compute asset return moments from the same series of risky asset returns as in the benchmark case, where now returns are in excess from yields to *i)* 10-year bonds and *ii)* real 3-month T-bills (computed as nominal yields net of inflation growth, with inflation measured as the variation in the CPI index for all urban consumers, all items). In the benchmark case we instead use returns in excess from yields to nominal 3-month T-bills.

The time series cover quarterly the sample 1980-2004 (100 observations); the 20 observations for real estate returns between 1980 and 1984 are imputed as in the benchmark case following Stambaugh (1997).

Results from this analysis are shown in Tables S2-S5, and in Figures S1-S2.

S.2.2. Time series period coverage

We compute asset return moments from the same series of risky and risk free asset returns as in the benchmark case, but using a shorter period coverage.

The time series cover quarterly the sample period 1990-2004 (60 observations).

Results from this analysis are shown in Tables S6-S7, and in Figure S3.

S.2.3. Time series for real estate returns

We compute asset return moments from the same series of risky and risk free asset returns as in the benchmark case, with the exception of real estate returns. Here we use the repeat-sale, purchase-only index calculated for the whole of the US by the Office of Federal Housing Enterprise Oversight (OFHEO) from data provided by Fannie Mae and Freddie Mac (the two biggest mortgage lenders in the US). To account for imputed rents, we increase returns by a constant factor of 5% as in Flavin and Yamashita (2002) and Pelizzon and Weber (2008).

The time series cover quarterly the sample 1980-2004 (100 observations); in this case no imputation of real estate returns is needed.

Results from this analysis are shown in Tables S8-S9, and in Figure S4.

S.3. Results using a different definition of portfolio

In this exercise we estimate risk tolerance for each household, taking the same asset returns as in the benchmark case, but changing the definition of portfolio. The new definition includes only (owner-occupied) residential housing as real wealth; consistently, we exclude from the portfolio other real estate properties and related loans.

Under the new definition, the inequality constraint imposed on real estate in the benchmark analysis (the optimal holding of real estate has to be not lower than the observed holding of residential housing) becomes an equality constraint (the optimal holding of real estate *coincides* with the observed holding of residential housing). Since the composition of the observed portfolio has changed, three further constraints are also different from the benchmark analysis: the equality constraints on human capital and real estate, and the inequality constraint on bonds (for which the optimal holding has to be not lower than the opposite of the observed holding on real estate).

The number of observations in the new dataset is slightly different than in the benchmark analysis (4,100 observations rather than 4,095) as we exclude from the original sample 20 observations (rather than 25) whose portfolios do not respect our constraints. It is also worth pointing out that, while the median wealth is virtually unchanged relative to the benchmark case (including human capital, it is 142,322 USD as opposed to 141,300 USD), the distribution of wealth in the sample changes, and the top 20% wealthiest households considered in the last column of Table S11 are not the same as the ones considered in the last column of Table 5 in the main text.

Results from this analysis are shown in Tables S10-S11, and in Figure S5.

Table S1. Heterogeneity of risk tolerance: specification with self-assessed measures

	Narrow def., unconstrained	Broad def., unconstrained	Broad def., constrained	
			Whole sample	Top 20% wealth
Age/100	-1.375	-5.445***	-15.228***	-37.206***
	(1.390)	(1.084)	(5.112)	(11.768)
Ln(income)/10	-5.922**	-14.983***	-7.873	-39.770**
	(2.275)	(1.731)	(7.870)	(15.926)
Ln(wealth)/10	22.107***	16.140***	29.035***	71.556***
	(0.762)	(0.637)	(3.036)	(13.610)
With children	-0.023	0.366	-1.074	-2.084
	(0.347)	(0.251)	(1.459)	(2.187)
Female	0.286	0.017	-3.763	-6.957
	(0.516)	(0.497)	(3.501)	(4.280)
Divorced	0.387	1.026**	8.138***	0.726
	(0.552)	(0.451)	(2.770)	(3.5610)
Widowed	-0.301	0.375	6.433	3.298
	(0.762)	(0.656)	(5.040)	(5.521)
Never married	0.142	-0.988*	2.855	-0.471
	(0.577)	(0.522)	(3.248)	(5.677)
Non-white	-0.702*	0.072	-0.205	-1.944
	(0.380)	(0.308)	(1.715)	(3.051)
High school graduate	0.282	-0.282	0.635	-6.457
	(0.861)	(0.744)	(2.180)	(12.963)
College graduate	0.959	-0.044	2.647	-0.981
	(0.875)	(0.786)	(2.705)	(12.967)
Employed	-0.304	0.546	0.489	-3.259
	(0.475)	(0.339)	(1.404)	(3.077)
Self-employed	-0.867	0.004	2.712	-2.457
	(0.596)	(0.387)	(2.946)	(3.264)
With financial advisor	0.288	-0.002	0.308	0.598
	(0.335)	(0.218)	(1.325)	(1.823)
Works in finance sector	0.714	-0.490	3.130	2.258
	(0.573)	(0.382)	(3.028)	(3.501)
Shops around	0.788**	0.473**	3.442**	0.602
for best rates on credit	(0.319)	(0.235)	(1.410)	(2.014)
Uses a computer	0.464	0.233	4.386**	5.100**
to manage money	(0.410)	(0.277)	(1.984)	(2.184)
N. financial institutions	0.209***	0.209***	1.398***	0.841**
where doing business	(0.066)	(0.044)	(0.343)	(0.423)
Self-assessed good health	-0.248	0.326	2.828*	0.629
	(0.356)	(0.261)	(1.608)	(2.076)
Optimistic about future	0.408	0.101	0.201	-0.122
	(0.310)	(0.233)	(1.441)	(1.878)
Self-assessed	0.269	0.124	-1.214	-3.345
short horizon planner	(0.344)	(0.266)	(1.505)	(2.579)
Self-assessed risk tolerant	2.101***	0.410	6.513**	4.933**
	(0.413)	(0.337)	(2.594)	(2.223)
Constant	-6.308***	10.229***	-6.699	-1.570
	(2.367)	(1.902)	(8.247)	(25.968)
Observations	4095	4095	4095	1602
Mult. imp. minimum dof	74.4	172.4	114.8	36.4
RT (γ) average household	0.101	0.113	0.239	0.373

The dependent variable is $\ln(1+\gamma)$*; all parameters and standard errors are multiplied by 100.*

Robust standard errors in parentheses. Method: OLS.

" RT (γ) *average household" is computed as* $\exp\left\{\overline{\ln(1+\gamma)}\right\}-1$ *where* $\overline{\ln(1+\gamma)}$ *is the sample average.*

****: significantly different from 0 at 1 percent; **: at 5 percent; *: at 10 percent.*

Table S2. Excess return time series statistics: numeraire, long-run horizon

Panel A. Historical excess returns (%)

Asset category	Bond	Stock	Real estate	Human capital
Mean	1.831	3.421	0.137	-1.498
Std. deviation	8.333	17.786	8.133	2.377
Sharpe ratio	21.972	19.232	1.683	-63.034

Risk free historical return: 7.831 percent.

Panel B. Covariances and correlations (%)

Asset category	Bond	Stock	Real estate	Human capital
Bond	0.694	*27.442*	*22.291*	*-1.238*
Stocks	0.407	3.163	*33.893*	*23.441*
Real estate	0.151	0.490	0.661	*52.714*
Human capital	-0.003	0.099	0.102	0.057

Correlations in Italic.

Panel C. Optimal portfolios (%)

Portfolio def.	Bond	Stock	Real estate	Human capital
Narrow	72.965	27.035	-	-
Broad	80.746	32.177	-39.200	26.276

Narrow definition: tangency portfolio. Broad definition: efficient portfolio with equality constraint on the human capital weight, and weights on risky assets summing to one.

Table S3. Heterogeneity of risk tolerance: numeraire, long-run horizon

	Narrow def., unconstrained	Broad def., unconstrained	Broad def., constrained	
			Whole sample	Top 20% wealth
Age/100	-2.264	-5.399***	-15.757***	-37.042***
	(1.375)	(1.006)	(4.733)	(11.348)
Ln(income)/10	-5.310**	-13.431***	-3.982	-35.092**
	(2.248)	(1.588)	(7.213)	(14.587)
Ln(wealth)/10	22.327***	15.420***	27.741***	68.072***
	(0.736)	(0.570)	(2.615)	(12.400)
With children	-0.056	0.390*	-1.408	-2.522
	(0.346)	(0.236)	(1.347)	(1.999)
Female	0.075	0.015	-4.515	-6.806*
	(0.516)	(0.457)	(3.391)	(3.888)
Divorced	0.615	0.991**	7.742***	0.957
	(0.549)	(0.423)	(2.686)	(3.043)
Widowed	-0.028	0.366	7.009	4.071
	(0.755)	(0.598)	(4.901)	(4.938)
Never married	0.331	-0.993**	3.486	0.949
	(0.577)	(0.485)	(3.194)	(5.850)
Non-white	-0.718*	0.051	0.561	-1.421
	(0.375)	(0.285)	(1.674)	(2.638)
High school graduate	0.175	-0.326	0.961	-1.981
	(0.854)	(0.684)	(2.061)	(11.811)
College graduate	0.941	-0.112	3.185	1.994
	(0.869)	(0.725)	(2.671)	(11.758)
Employed	-0.278	0.581*	0.411	-3.414
	(0.471)	(0.315)	(1.259)	(2.756)
Self-employed	-0.818	0.024	1.590	-2.231
	(0.590)	(0.362)	(2.384)	(2.949)
With financial advisor	0.277	0.009	0.236	0.266
	(0.333)	(0.205)	(1.231)	(1.657)
Works in finance sector	0.735	-0.474	3.320	2.954
	(0.569)	(0.360)	(2.903)	(3.532)
Shops around	0.780**	0.460**	2.788**	0.984
for best rates on credit	(0.317)	(0.219)	(1.259)	(1.740)
Uses a computer	0.592	0.234	4.588**	4.434**
to manage money	(0.406)	(0.260)	(1.900)	(1.940)
N. financial institutions	0.246***	0.207***	1.408***	0.943**
where doing business	(0.065)	(0.041)	(0.339)	(0.443)
Self-assessed good health	-0.217	0.306	2.706*	0.814
	(0.354)	(0.242)	(1.511)	(1.883)
Optimistic about future	0.500	0.115	0.384	0.250
	(0.307)	(0.214)	(1.334)	(1.641)
Constant	-6.398***	9.498***	-8.246	-5.278
	(2.343)	(1.743)	(7.635)	(23.271)
Observations	4095	4095	4095	1602
Mult. imp. minimum dof	81.2	166.5	166.5	76.1
RT (γ) average household	0.175	0.211	0.292	0.446

The dependent variable is $\ln(1+\gamma)$*, and is normalized to produce the same RT for the average household as the benchmark case. All parameters and standard errors are multiplied by 100.*
Robust standard errors in parentheses. Method: OLS.
" RT (γ) *average household" is computed as* $\exp\left\{\overline{\ln(1+\gamma)}\right\}-1$ *where* $\overline{\ln(1+\gamma)}$ *is the sample average.*
****: significantly different from 0 at 1 percent; **: at 5 percent; *: at 10 percent.*

Table S4. Excess return time series statistics: numeraire, nominal returns

Panel A. Historical excess returns (%)

Asset category	Bond	Stock	Real estate	Human capital
Mean	4.699	6.288	3.514	1.370
Std. deviation	8.339	17.486	7.402	2.303
Sharpe ratio	56.345	35.963	47.479	59.479

Risk free historical return: 4.963 percent.

Panel B. Covariances and correlations (%)

Asset category	Bond	Stock	Real estate	Human capital
Bond	0.695	*24.300*	*16.331*	*-1.892*
Stocks	0.354	3.058	*26.723*	*11.043*
Real estate	0.101	0.346	0.548	*33.057*
Human capital	-0.004	0.045	0.056	0.053

Correlations in Italic.

Panel C. Optimal portfolios (%)

Portfolio def.	Bond	Stock	Real estate	Human capital
Narrow	81.759	18.242	-	-
Broad	38.332	5.619	29.773	26.276

Narrow definition: tangency portfolio. Broad definition: efficient portfolio with equality constraint on the human capital weight, and weights on risky assets summing to one.

Table S5. Heterogeneity of risk tolerance: numeraire, nominal returns

	Narrow def., unconstrained	Broad def., unconstrained	Broad def., constrained	
			Whole sample	Top 20% wealth
Age/100	-2.290	-6.472***	-18.969***	-39.905***
	(1.405)	(1.192)	(4.820)	(11.324)
Ln(income)/10	-5.386**	-15.836***	-2.427	-32.982**
	(2.311)	(1.925)	(7.638)	(14.877)
Ln(wealth)/10	22.488***	17.167***	30.618***	71.542***
	(0.754)	(0.691)	(2.684)	(13.010)
With children	-0.081	0.399	-1.311	-2.663
	(0.355)	(0.280)	(1.361)	(2.131)
Female	0.063	-0.066	-3.984	-7.025
	(0.529)	(0.573)	(3.432)	(4.256)
Divorced	0.650	1.231**	8.454***	0.765
	(0.565)	(0.510)	(2.718)	(3.590)
Widowed	-0.007	0.532	6.618	3.904
	(0.775)	(0.763)	(4.966)	(5.462)
Never married	0.360	-1.036*	2.998	-0.879
	(0.591)	(0.593)	(3.147)	(5.386)
Non-white	-0.714*	0.066	-0.542	-1.739
	(0.383)	(0.345)	(1.619)	(2.946)
High school graduate	0.171	-0.356	1.210	-2.715
	(0.857)	(0.841)	(2.113)	(12.570)
College graduate	0.955	-0.054	3.634	2.902
	(0.873)	(0.896)	(2.729)	(12.520)
Employed	-0.271	0.624*	0.667	-2.869
	(0.484)	(0.377)	(1.356)	(3.012)
Self-employed	-0.799	0.000	2.849	-2.326
	(0.609)	(0.430)	(2.746)	(3.148)
With financial advisor	0.265	-0.019	0.464	0.426
	(0.342)	(0.244)	(1.254)	(1.799)
Works in finance sector	0.748	-0.530	2.687	2.020
	(0.585)	(0.426)	(2.751)	(3.332)
Shops around	0.806**	0.516*	3.415***	1.027
for best rates on credit	(0.325)	(0.263)	(1.301)	(1.958)
Uses a computer	0.618	0.305	4.556**	5.404**
to manage money	(0.418)	(0.308)	(1.818)	(2.124)
N. financial institutions	0.242***	0.244***	1.517***	0.844**
where doing business	(0.067)	(0.050)	(0.330)	(0.413)
Self-assessed good health	-0.200	0.373	2.696*	0.885
	(0.364)	(0.289)	(1.492)	(2.048)
Optimistic about future	0.515	0.123	0.536	0.469
	(0.314)	(0.258)	(1.332)	(1.839)
Constant	-6.477***	10.439***	-12.719	-11.178
	(2.400)	(2.103)	(7.792)	(24.385)
Observations	4095	4095	4095	1602
Mult. imp. minimum dof	90.8	149.3	90.9	73.7
RT (γ) average household	0.077	0.076	0.238	0.376

The dependent variable is $\ln(1+\gamma)$*, and is normalized to produce the same RT for the average household as the benchmark case. All parameters and standard errors are multiplied by 100.*
Robust standard errors in parentheses. Method: OLS.
" RT (γ) average household" is computed as $\exp\left\{\overline{\ln(1+\gamma)}\right\}-1$ *where* $\overline{\ln(1+\gamma)}$ *is the sample average.*
****: significantly different from 0 at 1 percent; **: at 5 percent; *: at 10 percent.*

Table S6. Excess return time series statistics: shorter time series

Panel A. Historical excess returns (%)

Asset category	Bond	Stock	Real estate	Human capital
Mean	4.107	6.319	4.847	1.462
Std. deviation	5.597	17.335	7.422	2.003
Sharpe ratio	73.375	36.454	65.303	73.017

Risk free historical return: 4.050 percent.

Panel B. Covariances and correlations (%)

Asset category	Bond	Stock	Real estate	Human capital
Bond	0.313	*-7.560*	*6.827*	*12.085*
Stocks	-0.073	3.005	*19.824*	*10.621*
Real estate	0.028	0.255	0.552	*31.449*
Human capital	0.014	0.037	0.047	0.040

Correlations in Italic.

Panel C. Optimal portfolios (%)

Portfolio def.	Bond	Stock	Real estate	Human capital
Narrow	84.877	15.123	-	-
Broad	44.105	6.129	23.490	26.276

Narrow definition: tangency portfolio. Broad definition: efficient portfolio with equality constraint on the human capital weight, and weights on risky assets summing to one.

Table S7. Heterogeneity of risk tolerance: shorter time series

	Narrow def., unconstrained	Broad def., unconstrained	Broad def., constrained	
			Whole sample	Top 20% wealth
Age/100	-3.078**	-6.498***	-18.304***	-31.032***
	(1.541)	(1.183)	(3.392)	(8.679)
Ln(income)/10	-4.394*	-16.198***	-10.670*	-32.488***
	(2.609)	(1.996)	(5.899)	(9.732)
Ln(wealth)/10	23.037***	17.905***	39.016***	77.964***
	(0.835)	(0.691)	(1.878)	(9.303)
With children	-0.280	0.477*	-2.346***	-3.740**
	(0.396)	(0.277)	(0.822)	(1.822)
Female	-0.134	-0.074	-2.376	-4.417
	(0.589)	(0.575)	(1.800)	(3.677)
Divorced	0.910	1.280**	4.857***	1.627
	(0.635)	(0.507)	(1.529)	(3.174)
Widowed	0.161	0.549	2.110	0.970
	(0.852)	(0.780)	(2.750)	(4.791)
Never married	0.621	-1.061*	0.469	-2.496
	(0.657)	(0.588)	(1.729)	(3.966)
Non-white	-0.954**	0.138	-0.601	0.159
	(0.416)	(0.340)	(0.912)	(2.510)
High school graduate	-0.052	-0.502	0.298	-0.038
	(0.811)	(0.838)	(1.850)	(9.847)
College graduate	0.996	-0.182	4.031*	5.369
	(0.836)	(0.895)	(2.074)	(9.808)
Employed	-0.174	0.682*	-0.083	-0.355
	(0.539)	(0.377)	(1.158)	(2.356)
Self-employed	-0.636	0.148	1.785	-0.719
	(0.695)	(0.437)	(1.545)	(2.460)
With financial advisor	0.240	-0.046	1.561*	1.372
	(0.384)	(0.244)	(0.807)	(1.551)
Works in finance sector	0.717	-0.520	1.105	0.699
	(0.666)	(0.424)	(1.281)	(2.300)
Shops around	0.908**	0.527**	1.864**	0.873
for best rates on credit	(0.366)	(0.261)	(0.778)	(1.627)
Uses a computer	0.811*	0.273	3.325***	3.766**
to manage money	(0.480)	(0.305)	(0.999)	(1.677)
N. financial institutions	0.271***	0.237***	1.246***	0.399
where doing business	(0.077)	(0.049)	(0.194)	(0.284)
Self-assessed good health	-0.053	0.400	1.332	-0.540
	(0.415)	(0.286)	(0.867)	(1.664)
Optimistic about future	0.518	0.054	0.698	0.098
	(0.350)	(0.256)	(0.785)	(1.548)
Constant	-7.769***	10.114***	-9.262	-26.290
	(2.663)	(2.136)	(5.882)	(17.968)
Observations	4095	4095	4095	1602
Mult. imp. minimum dof	74.5	165.1	58.5	36.3
RT (γ) average household	0.049	0.051	0.172	0.324

The dependent variable is $\ln(1+\gamma)$, *and is normalized to produce the same RT for the average household as the benchmark case. All parameters and standard errors are multiplied by 100.*
Robust standard errors in parentheses. Method: OLS.
" RT (γ) *average household" is computed as* $\exp\left\{\overline{\ln(1+\gamma)}\right\}-1$ *where* $\overline{\ln(1+\gamma)}$ *is the sample average.*
****: significantly different from 0 at 1 percent; **: at 5 percent; *: at 10 percent.*

Table S8. Excess return time series statistics: OFHEO series

Panel A. Historical excess returns (%)

Asset category	Bond	Stock	Real estate	Human capital
Mean	3.730	5.319	4.139	0.401
Std. deviation	8.719	17.624	4.201	2.492
Sharpe ratio	42.775	30.182	98.533	16.074

Risk free historical return: 5.932 percent.

Panel B. Covariances and correlations (%)

Asset category	Bond	Stock	Real estate	Human capital
Bond	0.760	*26.743*	*23.853*	*15.316*
Stocks	0.411	3.106	*4.697*	*16.668*
Real estate	0.087	0.035	0.177	*71.227*
Human capital	0.033	0.073	0.075	0.062

Correlations in Italic.

Panel C. Optimal portfolios (%)

Portfolio def.	Bond	Stock	Real estate	Human capital
Narrow	78.914	21.086	-	-
Broad	-12.429	14.402	71.751	26.276

Narrow definition: tangency portfolio. Broad definition: efficient portfolio with equality constraint on the human capital weight, and weights on risky assets summing to one.

Table S9. Heterogeneity of risk tolerance: OFHEO series

	Narrow def., unconstrained	Broad def., unconstrained	Broad def., constrained	
			Whole sample	Top 20% wealth
Age/100	-2.206	-2.459***	-11.087***	-13.614
	(1.362)	(0.457)	(3.680)	(9.767)
Ln(income)/10	-5.477**	-4.214***	-9.224*	-29.324***
	(2.358)	(0.776)	(5.351)	(10.600)
Ln(wealth)/10	22.390***	4.211***	22.597***	81.111***
	(0.769)	(0.260)	(2.061)	(10.028)
With children	-0.054	-0.006	-2.571***	-4.172**
	(0.346)	(0.106)	(0.813)	(2.036)
Female	0.085	-0.101	-2.430	-5.900
	(0.515)	(0.228)	(1.789)	(4.247)
Divorced	0.618	0.496**	3.671**	1.331
	(0.553)	(0.198)	(1.468)	(3.980)
Widowed	-0.025	0.247	3.335	3.684
	(0.768)	(0.308)	(2.475)	(5.403)
Never married	0.327	-0.206	1.955	0.635
	(0.576)	(0.231)	(1.908)	(4.695)
Non-white	-0.689*	-0.075	-1.410	-4.712*
	(0.377)	(0.131)	(0.931)	(2.435)
High school graduate	0.195	-0.069	1.430	5.303
	(0.852)	(0.320)	(1.420)	(8.031)
College graduate	0.948	0.142	4.458***	10.239
	(0.865)	(0.343)	(1.646)	(8.074)
Employed	-0.283	0.141	-1.136	-1.693
	(0.462)	(0.150)	(1.315)	(2.653)
Self-employed	-0.822	-0.116	-0.425	-3.750
	(0.583)	(0.173)	(1.559)	(2.687)
With financial advisor	0.268	0.020	1.193	0.989
	(0.350)	(0.100)	(0.791)	(1.708)
Works in finance sector	0.747	-0.174	0.177	-1.815
	(0.556)	(0.156)	(1.062)	(2.187)
Shops around	0.790**	0.151	1.601**	0.391
for best rates on credit	(0.317)	(0.101)	(0.786)	(1.758)
Uses a computer	0.592	0.243**	3.401***	4.574**
to manage money	(0.417)	(0.118)	(0.900)	(1.874)
N. financial institutions	0.239***	0.100***	1.112***	0.733**
where doing business	(0.071)	(0.022)	(0.224)	(0.294)
Self-assessed good health	-0.219	0.142	1.118	0.566
	(0.359)	(0.114)	(0.877)	(1.785)
Optimistic about future	0.512	0.105	1.322*	2.031
	(0.330)	(0.099)	(0.794)	(1.824)
Constant	-6.311***	4.607***	-1.378	-54.341***
	(2.390)	(0.816)	(5.776)	(17.704)
Minimum obs	4095	4095	4095	1602
Mult. imp. minimum dof	89.0	148.0	27.2	56.3
RT (γ) average household	0.101	0.043	0.171	0.319

The dependent variable is $\ln(1+\gamma)$, *and is normalized to produce the same RT for the average household as the benchmark case. All parameters and standard errors are multiplied by 100.*
Robust standard errors in parentheses. Method: OLS.
" RT (γ) *average household" is computed as* $\exp\{\overline{\ln(1+\gamma)}\}-1$ *where* $\overline{\ln(1+\gamma)}$ *is the sample average.*
****: significantly different from 0 at 1 percent; **: at 5 percent; *: at 10 percent.*

Table S10. Summary statistics: only residential housing as real estate

Portfolio def.	Representative agent		Household-specific (median)	
	Risk tolerance	**Expected return gap (%)**	**Risk tolerance**	**Expected return gap (%)**
Narrow, unconstrained	0.212 (0.204, 0.219)	0.903 (0.823, 0.991)	0.080 (0, 0.345)	0.116 (0, 2.669)
Broad, unconstrained	0.120 (0.117, 0.124)	0.771 (0.737, 0.808)	0.111 (0.022, 0.285)	0.935 (0.073, 7.304)
Broad, constrained	0.356 (0.329, 0.384)	0.268 (0.245, 0.290)	0.114 (0.008, 0.822)	0.026 (0, 0.598)

In parentheses: Representative agent: 95% confidence interval based on 1,000 bootstrap simulations over the household units. From each simulation we compute the aggregate portfolio using the sampling weights, and separately for the five imputations; Household-specific: 2.5 and 97.5% quantiles of the empirical distribution.

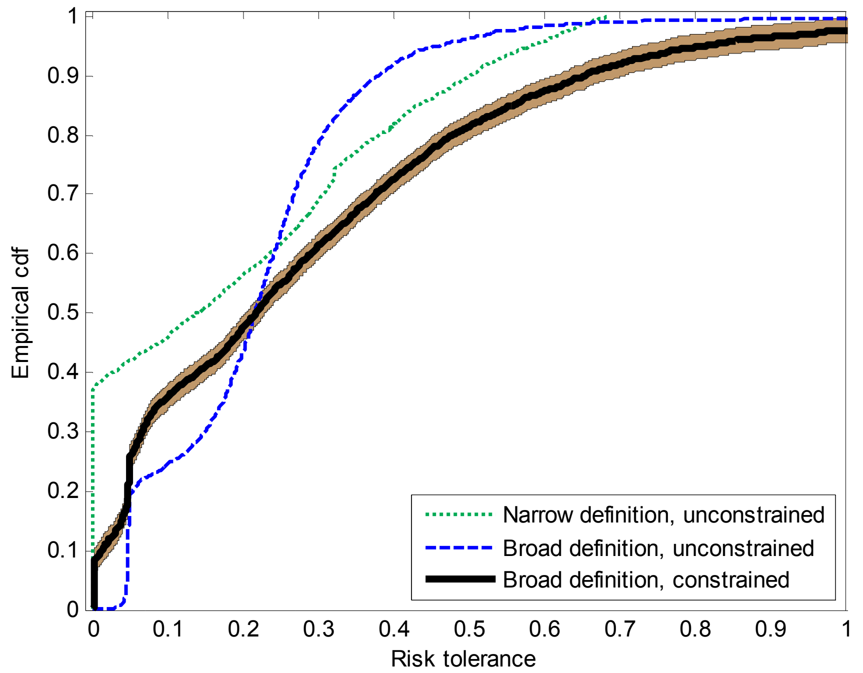
Table S11. Heterogeneity of risk tolerance: only residential housing as real estate

	Narrow def., unconstrained	Broad def., unconstrained	Broad def., constrained	
			Whole sample	Top 20% wealth
Age/100	-2.252	-5.624***	-16.463***	-28.429***
	(1.387)	(1.065)	(2.787)	(9.527)
Ln(income)/10	-5.516**	-15.626***	-10.641**	-25.325**
	(2.270)	(1.759)	(5.122)	(10.548)
Ln(wealth)/10	22.393***	16.398***	28.994***	88.212***
	(0.743)	(0.614)	(1.497)	(11.051)
With children	-0.057	0.391	-1.044	-3.790*
	(0.349)	(0.245)	(0.668)	(1.958)
Female	0.067	0.346	-0.365	-3.099
	(0.521)	(0.404)	(1.070)	(3.672)
Divorced	0.647	0.777*	2.843**	-2.589
	(0.554)	(0.424)	(1.130)	(3.398)
Widowed	-0.010	-0.221	-0.007	-0.549
	(0.764)	(0.456)	(1.564)	(4.814)
Never married	0.328	-1.347***	-0.785	-2.760
	(0.581)	(0.481)	(1.204)	(4.012)
Non-white	-0.678*	-0.059	-2.180***	-6.913***
	(0.379)	(0.301)	(0.694)	(2.489)
High school graduate	0.190	-0.379	-0.232	7.539
	(0.863)	(0.740)	(1.469)	(7.167)
College graduate	0.962	-0.126	2.647*	13.305*
	(0.878)	(0.768)	(1.565)	(7.167)
Employed	-0.307	0.574*	0.258	-1.689
	(0.476)	(0.345)	(1.016)	(2.636)
Self-employed	-0.783	0.060	0.204	-3.511
	(0.597)	(0.392)	(1.285)	(2.719)
With financial advisor	0.275	0.078	1.723**	2.945*
	(0.336)	(0.215)	(0.678)	(1.707)
Works in finance sector	0.741	-0.600	-0.319	-1.494
	(0.574)	(0.387)	(1.050)	(2.432)
Shops around	0.783**	0.505**	1.505**	0.468
for best rates on credit	(0.320)	(0.233)	(0.651)	(1.779)
Uses a computer	0.558	0.151	2.254***	2.313
to manage money	(0.410)	(0.275)	(0.831)	(1.899)
N. financial institutions	0.245***	0.165***	0.875***	0.386
where doing business	(0.066)	(0.043)	(0.157)	(0.300)
Self-assessed good health	-0.218	0.282	1.147	-1.472
	(0.357)	(0.257)	(0.728)	(1.778)
Optimistic about future	0.507	0.166	1.503**	2.159
	(0.310)	(0.221)	(0.623)	(1.683)
Constant	-6.254***	11.001***	-0.891	-58.391***
	(2.365)	(1.914)	(5.096)	(17.602)
Minimum obs	4100	4100	4100	1595
Mult. imp. minimum dof	96.1	180.3	94.7	26.2
RT (γ) average household	0.101	0.110	0.188	0.322

The dependent variable is $\ln(1+\gamma)$*, and is normalized to produce the same RT for the average household as the benchmark case. All parameters and standard errors are multiplied by 100.*
Robust standard errors in parentheses. Method: OLS.
" RT (γ) *average household" is computed as* $\exp\left\{\overline{\ln(1+\gamma)}\right\}-1$ *where* $\overline{\ln(1+\gamma)}$ *is the sample average.*
****: significantly different from 0 at 1 percent; **: at 5 percent; *: at 10 percent.*

Figure S1. Empirical cumulative distributions: numeraire, long-run horizon

Panel A. Risk tolerance



Panel B. Expected return gap

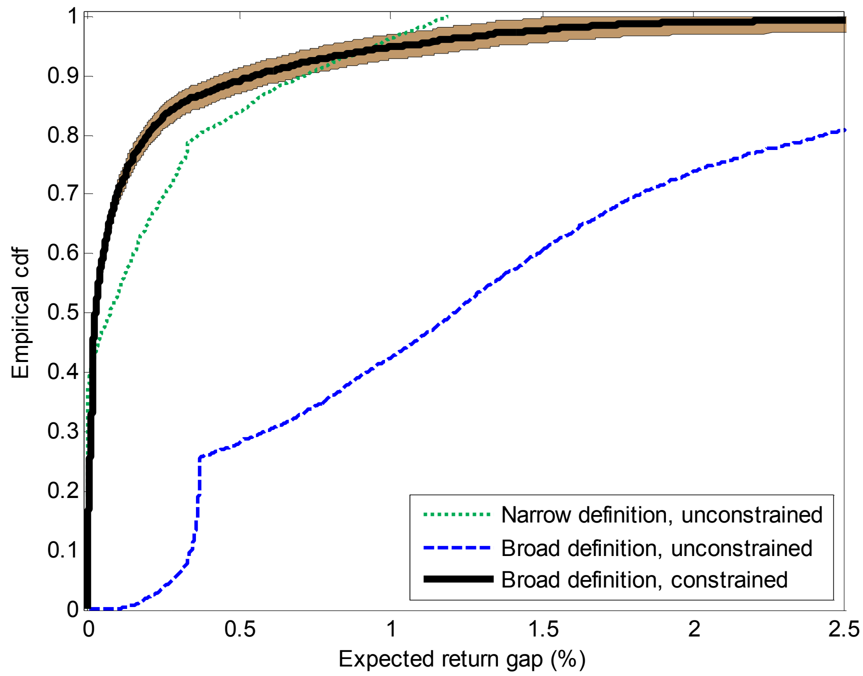
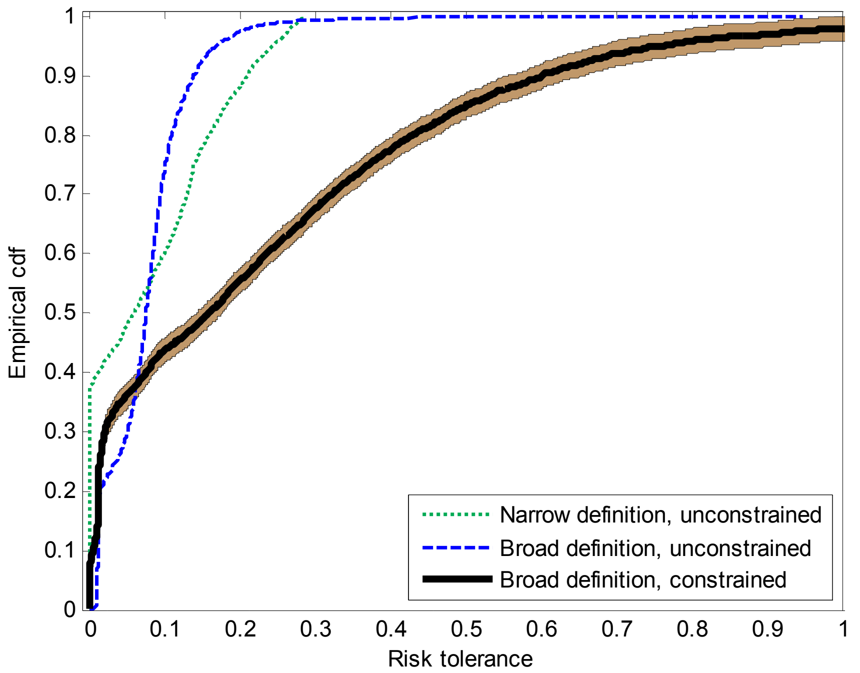


Figure S2. Empirical cumulative distributions: numeraire, nominal returns

Panel A. Risk tolerance



Panel B. Expected return gap

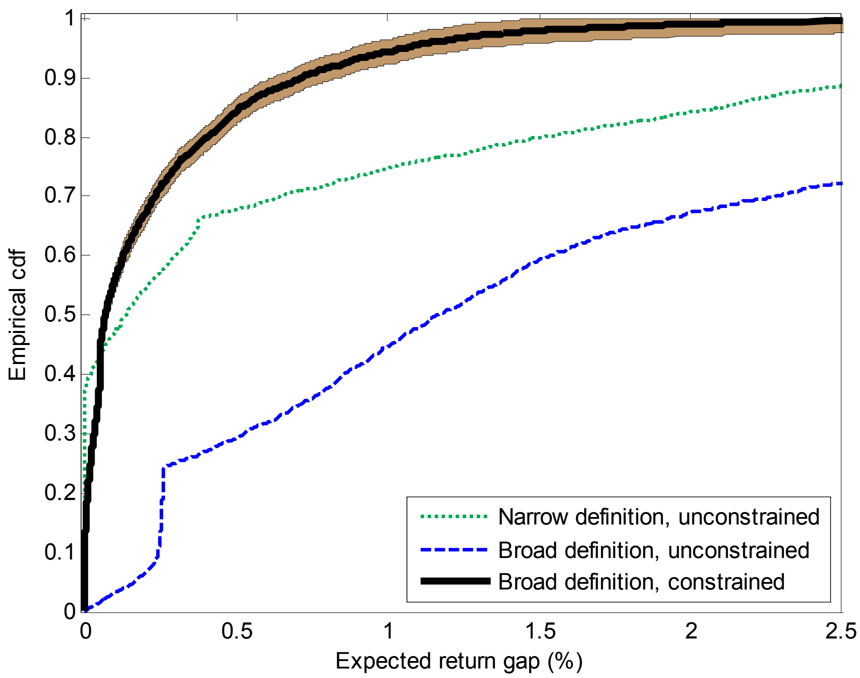
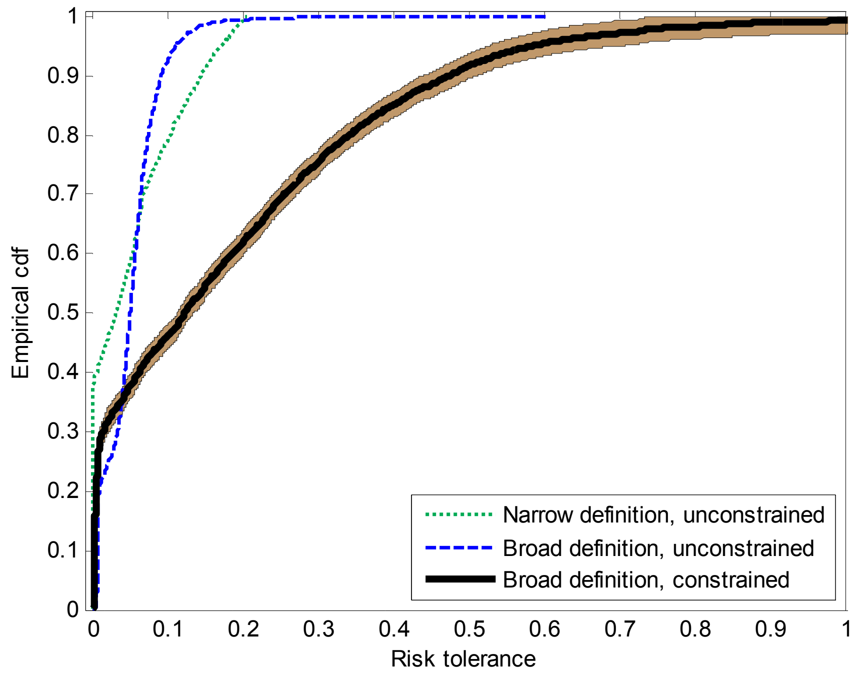


Figure S3. Empirical cumulative distributions: shorter time series

Panel A. Risk tolerance



Panel B. Expected return gap

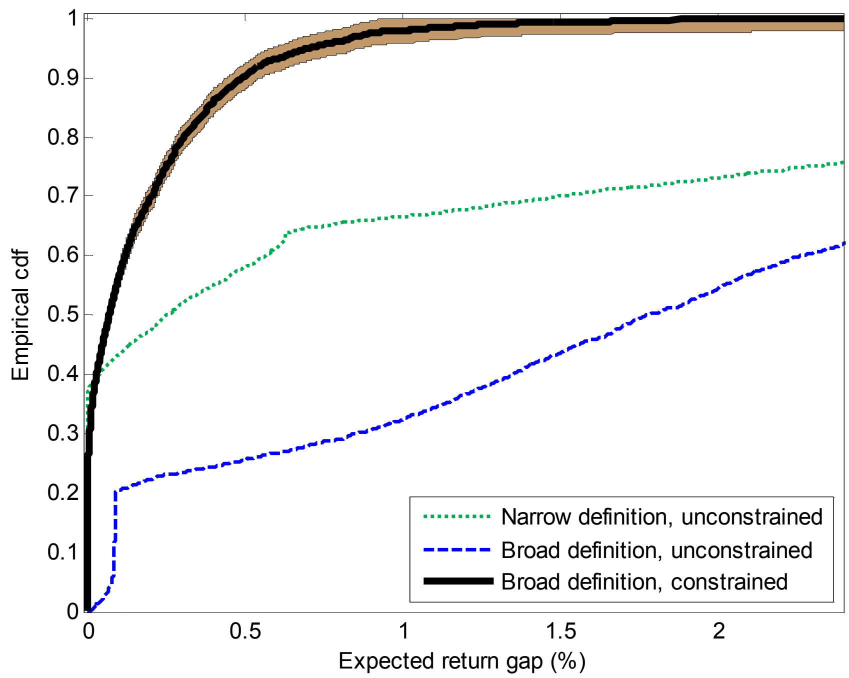
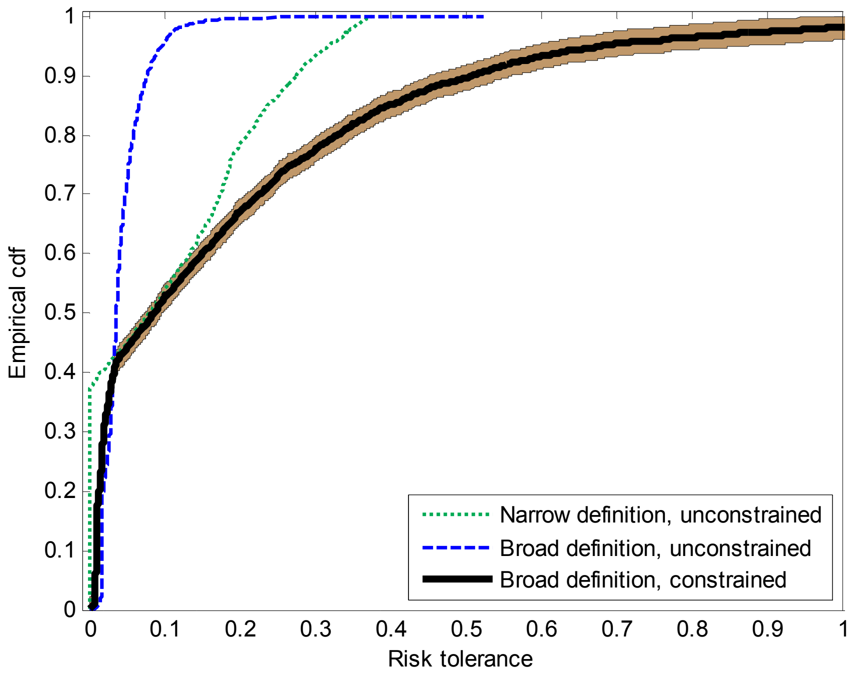


Figure S4. Empirical cumulative distributions: OFHEO series

Panel A. Risk tolerance



Panel B. Expected return gap

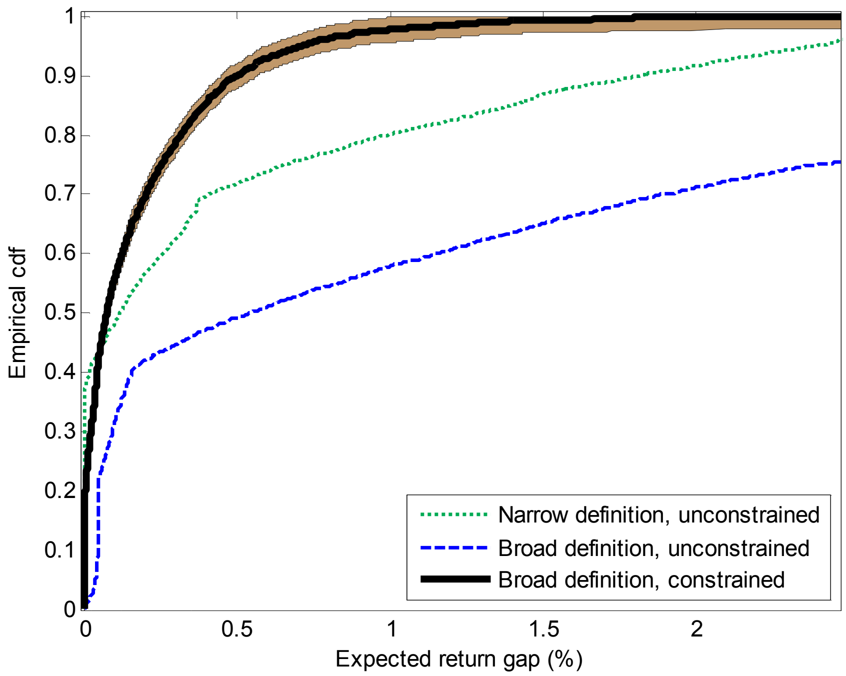
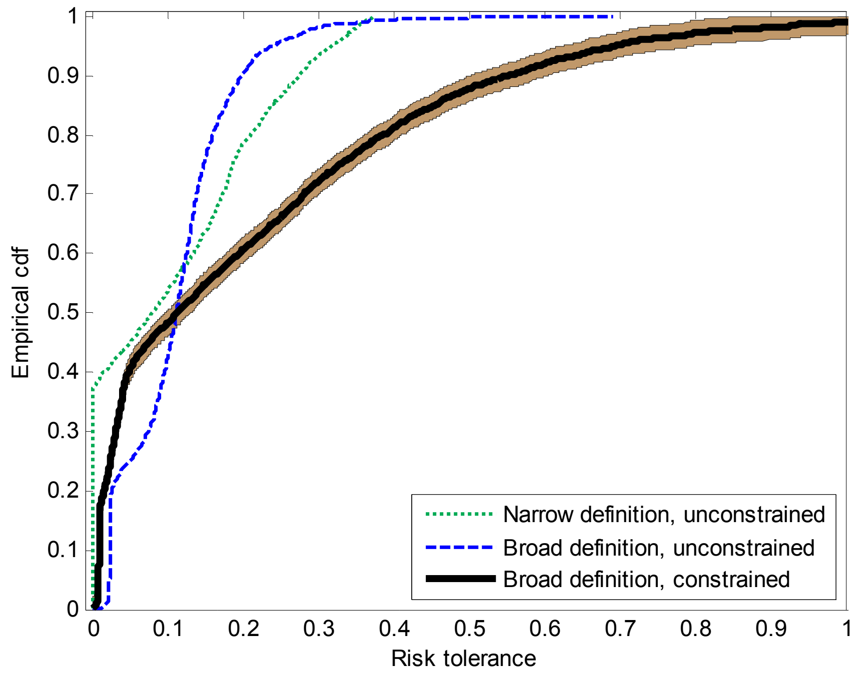


Figure S5. Empirical cumulative distributions: only residential housing as real estate

Panel A. Risk tolerance



Panel B. Expected return gap