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Efficient portfolios when housing needs change over the life cycle

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ABSTRACT

We address the issue of the efficiency of household portfolios in the presence of housing risk. We treat housing stock as an asset and rents as a stochastic liability stream: over the life cycle, households can be short or long in their net-housing position. Efficient financial portfolios are the sum of a standard Markowitz portfolio and a housing risk hedge term that multiplies net housing wealth. Our empirical results show that net housing plays a key role in determining which household portfolios are inefficient. The largest proportion of inefficient portfolios obtains among those with positive net housing, who should invest more in stocks.

1. Introduction

The role of real estate in personal portfolio management is controversial, and often neglected in the finance literature. Allowing housing wealth into total wealth in the analysis of portfolio choice raises conceptual issues: the main residence provides essential housing services, and it is less than obvious that it should be considered as wealth. Also, housing needs change with age, particularly because of demographics. Demographics drive housing needs up in the first half of the life cycle, down in the second half, very much the same way they also affect non-durable consumption (Attanasio et al., 1999). Consumers can meet their housing needs in two different ways: they can rent housing services, or they can purchase housing stock. When the price of renting positively correlates with house prices, home-ownership is a way to reduce the risk related to the consumption of housing services, as argued in Sinai and Souleles (2005).

The way we address the issue of optimal portfolio choice in the presence of housing risk is to explicitly treat housing stock as an asset, and rents as a stochastic liability stream in the sense of Elton and Gruber (1992). We derive conditions under which standard mean–variance analysis holds once wealth includes the value of real estate net of the rent liability. Our wealth definition allows us to distinguish between investors who are long on housing, or "over-housed" (the value of the housing stock they own exceeds the present value of future housing services, that is they have a long net-housing position) and short on housing, or "under-housed" (vice versa, short net-housing position). The former group (which includes elderly home-owners) is more exposed to house price risk, the latter (which includes tenants and young home-owners whose housing needs are increasing) to rent risk.

We develop a life cycle model that allows housing consumption needs to change with age, but assumes that they are given to the household. To satisfy them, households can rent or own housing stock, but in both cases they bear risks, because the price of the house and the rental rate are driven by a single stochastic process that correlates with financial assets returns. We derive conditions under which the analysis can be carried out in a static mean–variance framework. Our model, which extends Flavin and Yamashita (2002), Yao and Zhang (2005) and Flavin and Nakagawa (2008), implies that households should allocate financial assets with two objectives in mind: to maximize the expected return of their portfolio, given a certain risk (standard Markowitz portfolio), and to hedge the risk in their net-housing position.

In the empirical application, we derive the optimal financial portfolios for any given net-housing position and ask whether household portfolios are in line with these optimal portfolios, that is whether they are efficient, given the presence of housing risk. We test conditional efficiency by computing a statistic that is based on the financial portfolio Sharpe Ratio (the ratio of the mean excess return to the standard deviation) after allowance has been made for the hedge term (the conditional efficiency test statistic

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is derived in Gourieroux and Jouneau (1999)). The aim of our application is to evaluate the empirical relevance of housing risk in household portfolios. In particular, we compare the efficiency of asset allocations for households who are over-housed, under-housed or have net-housing positions close to zero.

We analyze household portfolio data from the Italian 2002 Survey on Household Income and Wealth (2002). This survey is run by the Bank of Italy and contains detailed information on a number of financial variables, such as self-reported values for household portfolio positions, as well as on the market and rental value of the main residence. It also contains records on earnings, expected or actual retirement age, occupation and pension income of each individual in the household. For each household we impute a value for human capital and for the present value of future rents, by exploiting information available in previous waves of the survey (SHIW waves from 1989 to 2000). We also use data on financial assets returns and on housing returns from other sources.

The paper is organized as follows. In the next section we present the intuition of our empirical strategy and relate it to the literature on the role of housing investment in portfolio choice (the formal dynamic model is derived in Pelizzon and Weber (2007)). In Section 2, data are described and empirical results are presented in Section 3. In Section 4, robustness analysis is presented and conclusion is given in Section 5.

2. Analysis conditional on housing

Standard mean–variance analysis (Tobin, 1958; Markowitz, 1952) implies that the vector of asset holdings should satisfy:

$$\underline{X}_0^{*T} = \left[\frac{-\frac{\partial U}{\partial FW}}{\frac{\partial^2 U}{\partial FW^2}}\right] \Sigma^{-1} \underline{\mu}^T \qquad (1)$$

where FW is financial wealth, Σ is the variance–covariance matrix of returns on N risky assets, and μ is the row vector of expected excess returns (that is, returns in excess of the risk-free rate). The sum of the X's is the wealth invested in risky assets. $U(FW)$ is the utility function: in the simplest case, investors are assumed to maximize the expected utility of end-of-period wealth and returns are normally distributed.

Eq. (1) can be derived in a dynamic model where all wealth is invested in liquid financial assets whose returns follow Brownian motions with time-invariant parameters (Merton, 1969).

However, things may change when some assets are illiquid, and therefore are traded infrequently, such as housing. There are circumstances where the standard analysis applies even in the presence of illiquid real assets over those periods when these are not traded (Grossman and Laroque, 1990; Flavin and Nakagawa, 2008). But in the more general case where housing returns correlate with financial assets returns, the standard analysis fails to capture the presence of a hedge term in the optimal portfolio (Damgaard et al., 2003).[1]

In this paper we take the view that consumers know how their housing needs evolve over time, and optimally choose whether to purchase or rent housing stock. Consumption of housing services may be lower or higher than the service flow of the housing stock owned: if it is lower, some services are rented, if higher, part of the housing stock is let to other consumers. The existence of a rental market allows consumption and investment motives to be separated, but the presence of housing needs implies that investment decisions are affected by current and future consumption of housing. In this context, we show how the optimal financial portfolio changes when the difference between housing needs and housing owned is non-zero, and how to assess whether observed household portfolios are indeed efficient.

We assume that consumers enjoy utility from non-durable consumption and from housing, and housing services can be obtained by either renting or owning a certain housing stock. We also assume that rent rates correlate with housing stock returns. We first consider the special case where there is unit correlation, then we explore the more general case with a positive, fixed correlation coefficient lower than 1. The former case corresponds to a situation where owning is a perfect hedge, as in Yao and Zhang (2005); the latter to the more general situation where house owning is not a perfect hedge against rent risk.

Crucial to our analysis is that consumers do not live forever: the maximum length of life is T. They can die in each period with a given, age-specific probability. Consumers care about their children, i.e. there is a bequest motive in their life-time utility function, but they wish to bequeath wealth, not housing. Housing can be bequeathed, but it is only valued for its monetary value, nothing else. Finally, housing needs evolve with age in a deterministic manner.

In the model, we make the strong assumption that housing consumption equals housing needs, that is housing consumption is an exogenously given function of age. Consumers can invest their wealth in a risk-free asset, that is an asset whose return is known in terms of the non-durable good, n risky financial assets and housing stock. Housing services are provided by the housing stock that can be either rented or owned. All asset returns (including the housing return) follow Brownian motions, and they correlate with each other. Human capital is instead assumed to be a risk-free investment (or it has non-systematic risk, see Bodie et al. (1992)).

In this context, the relevant notion of housing wealth is the difference between housing stock owned and the present value of current and future rents. Typically, this position is negative for young households who are likely to trade up in the housing market, it is positive for old households, whose housing needs are decreasing and are instead interested in the liquidation value of the house because they wish to trade down, as stressed in Banks et al. (2004), or have a bequest motive. In this model, home-ownership provides insurance against rent risk, see Sinai and Souleles (2005). Rents are a stochastic liability stream, similarly to pension payments for pension funds (Elton and Gruber, 1992; Campbell and Viceira, 2005).

In this model, which is presented in the appendix of Pelizzon and Weber (2007), if households have non-zero positions in housing (that is, if their home is worth more or less than the present value of their future housing needs), and if financial returns have non-zero correlations with housing returns, the standard analysis is no longer valid. In fact, one can show that, when owning is a perfect hedge against rent risk, efficient portfolios satisfy the following relation:

$$\underline{X}_0^{T*} = \left[\frac{-\frac{\partial J}{\partial TW}}{\frac{\partial^2 J}{\partial TW^2}}\right] \Sigma^{-1} \underline{\mu}^T - P_0 D_0 \Sigma^{-1} \Gamma_{bP}^T \qquad (2)$$

where TW denotes total wealth (the sum of financial wealth, FW; human capital, HC; and the value of the home, H; net of debt and of the present value of future rents), P_0D_0 is defined as the difference between the value of the home, H, and the present value of future rents (housing needs). Γ_{bp} denotes the (row) vector of covariances between the return on housing and on risky financial assets and J is the value function of the intertemporal optimization problem.

[1] In the literature on efficient portfolios few papers incorporate real estate as an asset. Goetzmann and Ibbotson (1990), Goetzmann (1993) and Ross and Zisler (1991) concentrate on risk and return of real estate investment. Flavin and Yamashita (2002), Yao and Zhang (2005), Flavin and Nakagawa (2008) and Pelizzon and Weber (2008) characterize the efficiency frontier for house owners, under different assumptions about rent risk and the correlation of housing returns with financial assets. Finally, Cocco (2005) finds that housing can help explain limited stock market participation.

Eq. (2) reveals that the optimal portfolio is the sum of a standard Markowitz portfolio and a hedge term (see also Mayers (1973) and Anderson and Danthine (1981)). The former is multiplied by the inverse of absolute risk aversion, whereas the latter is not. This implies that risk-averse investors should hedge housing return risk in exactly the same way, for a given net-housing position.

In the sequel of the paper we shall show the importance of the net-housing position as defined here. Gross housing wealth apparently accounts for the largest portion of the sum of financial and real wealth, but this does not take into account the future rents liability, that is overall of comparable magnitude as housing wealth, even though it differs greatly across households.

Mean–variance efficiency is sometimes assessed on the basis of a graphical comparison, but this does not take into account that the efficiency frontier is not known, rather it is estimated. To establish whether a portfolio is indeed efficient we need to take into account this source of variability, that is we need to use a formal statistical test. We can test whether household portfolios are efficient conditionally on housing by computing a statistic that is based on the financial portfolio Sharpe ratio[2] after allowance has been made for the hedge term. In fact, Gourieroux and Jouneau (1999) derive an efficiency test for the conditional or constrained case, i.e. for the case where a subset of asset holdings is potentially constrained (housing, in our case).

The intuition behind the test is the following. The standard test for portfolio efficiency is based on (the square of) the Sharpe ratio. The Sharpe ratio is in fact the same along the whole efficient frontier (with the exception of the intercept), which is along the capital market line. This test breaks down when one asset is taken as given, because the efficient frontier in the mean–variance space corresponding to all assets is no longer a line, rather a curve. However, Eq. (2) implies that we can go back to the standard case when the analysis is conducted conditioning on a particular asset, once the hedge term component is subtracted from the observed portfolio.

3. Application

To show the implications of our theoretical analysis we use data on Italian asset returns and household portfolios. Italy provides a good test case to study the effect of housing on portfolios because home-ownership is wide spread and household stock market participation, while low, has greatly increased in recent years (Guiso et al., 2002), but also because in Italy housing returns correlate with financial returns, thus providing the need for a hedge term in home-owners' portfolios. A convenient feature of Italy for our purposes is that pension wealth, the amount of which is typically not recorded in survey data, is still almost entirely provided by the public pay-as-you-go social security system and is therefore both out of individual investors' control and not directly related to the financial market's performance. Finally, mortgages are rare compared to countries like the US or the UK, and particularly reverse mortgages (equity lines) are not yet available.

In our application we use household portfolio data for 2002 and asset return data for the period 1989–2002.

The most widely used Italian survey data, the Bank of Italy-run Survey on Household Income and Wealth (SHIW), shows direct or indirect participation in equity markets (broadly defined to include life insurance and private pensions) at 34.89% in 2002. For comparison, the percentage of home-owners in the same year was 69.01%. In fact, the survey contains detailed information on asset holdings of 8011 households as of 31.12.2002, as well as self-assessed value of their housing stock (both principal residence and other real estate) and actual or imputed rent for each dwelling. For each household we also know the region of residence and a number of demographic characteristics. It does cover a relatively large number of assets, including individual pension funds: however, these are still remarkably unimportant in Italy, partly because of inadequate tax incentives. Occupation pension schemes are also relatively minor, even though recent reforms of the Italian Social Security system (particularly the 1995 Dini reform) imply that they should become widespread.[3] Further details on financial and real asset information are provided in Pelizzon and Weber (2007).

Asset return data cover four major assets: short-term government bonds (6-month BOT), corporate bonds, government bonds, and equity (the MSCI Italy stock index). We treat the short-term bond as risk free, and assume that this is the relevant return on bank deposits, once account is taken of non-pecuniary benefits.[4]

To evaluate the efficiency of households' portfolios we need to determine the expected return and the expected variance covariance matrix of the assets. Given long, stationary series we could simply compute the corresponding sample moments of the assets excess returns. However, this approach is unlikely to work in our case: our sample period is 1989–2002 (and cannot be extended because some assets did not exist prior to the mid-1980s), and in the 1990s we observe a long convergence process of Italian interest rates to German interest rates, which accelerated dramatically in the few years before the introduction of the Euro on January 1999.

We exploit prior information on convergence by using a simple Weighted Least Squares procedure,[5] where the raw return series data are down weighted more the farther away they are from December 1998 (they have a unitary weight from 1999 on). More precisely, we construct the weights to be a geometrically declining function of the lag operator multiplied by α (where α is set to 0.9). The weighted series are used to compute sample first and second moments.[6]

In Table 1 we show the first and second moments of the excess returns data we use (1989–2002). These are expressed as percentage annual rates of return net of the time-varying risk-free rate.

We see that stocks have higher expected excess return (4.9%) and higher variance than all other risky financial assets. Government bonds also have high expected excess return (4.1%), due to their long maturity. Corporate bonds rank last both in terms of expected excess return (2.3%) and variance.[7]

[2] These slopes are of course the Sharpe ratios, which relate directly to expected utility, as shown in Gourieroux and Monfort (2003).

[3] Further information on the survey is provided in Guiso et al. (2002) and Biancotti et al. (2004). Information on the Italian pension system and its recent reforms is presented in Brugiavini and Fornero (2001). For issues related to portfolio choice and contribution pension plans, see Karlsson and Nordén (2007).

[4] We derive the holding period returns (HPR) as follows. For government bonds we take the MSCI Italian Government bond index after 1993. Prior to December 1993 this index is not available, and we use our own estimates of the term structure based on quoted prices of Italian government bonds to determine the holding period return by assuming a duration of 5 years. For corporate bonds we derive the prices consistent with the RENDIOBB index (the index of Italian corporate bonds yields) and assume a duration of 3 years. We express all returns net of withholding tax, on the assumption that for most investors other tax distortions are relatively minor (financial asset income is currently subject to a 12.5% withholding tax. Housing is taxed on the basis of its ratable value, while actual rental income is taxed at the marginal income tax rate).

[5] Estimation error is of particular concern for first moments and calls for use of prior information in estimation (see for instance Merton (1980) and Jorion (1985)).

[6] A similar procedure for second-order moments is often used in the financial industry (see RiskMetrics (1999)) and can be shown to be equivalent to particular GARCH models (Phelan, 1995).

[7] Our estimated excess return on equity (4.9%) is not far from what is found using much longer sample periods: Dimson et al. (2006) report a 5.7% average equity premium over the 1950–2000 period, in line with secular evidence provided by Panetta and Violi (1999). Our expected excess return for corporate bonds is also similar to the one reported by Dimson et al. (2006) for medium term bonds (2.5%) over the 1950–2000 period. Long-term government bonds unfortunately did not exist prior to our estimation period, so no comparison with other sources is possible.

Table 1
Sample first and second moments of annual excess returns.

	Government bonds	Corporate bonds	Stocks
Expected return %	4.0981	2.2845	4.9011
Standard deviation %	5.2383	3.2169	28.9950
Correlation			
Government bonds	1	0.8404	0.0215
Corporate bonds		1	0.1726
Stocks			1

Table 2
Expected excess returns and correlation matrix of housing (1989–2002).

	North West	North East	Centre	South
Expected excess return %	3.2922	4.1883	3.2791	3.3036
Standard deviation %	5.5774	5.0755	6.5381	5.0715
Government bonds	−0.0164	−0.1169	−0.1161	−0.2036
Corporate bonds	−0.0843	−0.1691	−0.2177	−0.1998
Stocks	−0.5057	−0.2790	−0.4172	−0.1506

Correlation coefficients between bonds are quite high (.84). Correlation coefficients of stocks and bonds are positive, but much smaller. Not surprisingly, stock returns correlate more with corporate bonds (.17) than with government bonds (.02).

This picture is however largely incomplete. We know that two households out of three own real estate, and we argue that this type of investment is highly illiquid. Even those who do not own housing stock consume housing services and should hedge the risk of future purchases of either stocks or services. It is therefore of great interest for us to compute first and second moments of the housing stock return. To this end we use province-level quality-adjusted biannual price data (described in Cannari and Faiella (2008)) covering the whole 1989–2002 period. We compute the return on housing as in Flavin and Yamashita (2002).

Finally, we aggregate housing returns in four macro-regions: North West, North East, Centre and South (we use provincial resident population numbers to generate weights).[8] The first and second moments are then determined using (prior to 1999) the time-varying weights described above.

Table 2 reveals that expected excess returns on housing are highest in the North East and in the South, and lowest in Central Italy (they range between 3.3% and 4.2% on an annual basis). They are close to returns on bonds, but are much lower than returns on stocks. Housing excess return standard deviations range between 5.1% and 6.5%, and are therefore much lower than on stocks, but comparable to bonds. Of interest to us is the negative correlation between housing returns and most financial asset returns.

The issue arises of whether these correlations are of economic interest: we know from Eq. (2) that what matters for portfolio choice is not simple correlations, rather partial correlations, as summarized by the OLS slope coefficients. We can estimate the coefficients of the hedge term in Eq. (2), that is the beta hedge ratio $\Sigma^{-1}\Gamma_{bP}$, by running the regression of housing returns on financial asset returns. Parameter estimates and their standard errors are summarized in Table 3.

We see that in two regions (North West and Centre) there is at least one non-zero parameter at the 95% significance level and in all regions the slope coefficients are jointly significantly different from zero at the 95% level (the p-value of the F-test is reported at the bottom of the table, together with the R^2). The region where this test is least significant is the North East (with a p-value of 3%).

On the basis of this evidence, we conclude that housing returns present significant (partial) correlations with financial asset returns in Italy, and this provides the basis for introducing a hedge term in household portfolios of house-owners.[9]

The analysis of Section 1 highlights that the relevant wealth concept is the sum of financial wealth, human capital, and housing wealth net of the present value of future rents (PVR) and total debt. Two key variables are not directly observable and have to be constructed: human capital and the present value of housing needs. To compute the former, for each individual in SHIW 2002 we would like to know current and future earnings, current and future pension income, as well as retirement and survival probabilities. To compute the latter, we would like to know current rent (actual or imputed) and its likely changes in the future that relate to changes in family size and composition, to retirement or death of either spouse, or indeed to changes in economic circumstances of the household. These data, combined with survival probabilities, could be used to calculate a household-specific measure of the PVR, the present value of current and future housing needs.

Only a small part of these data are available in SHIW 2002, but further relevant information can be found in previous waves of SHIW (which refer to 1989, 1991, 1993, 1995, 1998 and 2000).

The method we adopt is to use the pooled SHIW data to estimate some relations (for earnings and rent), controlling for age, year of birth and a few characteristics, and use the estimated profiles to project forward the current values reported by SHIW 2002 respondents. These projections are then multiplied by the relevant (age and gender specific) survival probabilities and discounted to get a household-specific estimate of Human Capital and PVR. Pelizzon and Weber (2007) provide further details.

Table 4 shows average and median amounts for the broad assets and liabilities we consider: four financial assets, three types of debt, housing, the present value of rent and human capital.[10] We see that financial assets are a relatively small component of total wealth: their average is in the € 23,000 region, whilst average total wealth is close to € 500,000. By far the largest component of total wealth is human capital, which is computed as the present value of future earnings and pension payments and is treated as a risk-free asset. This is a constructed variable, and therefore sensitive to the particular assumptions made on discount factors, earnings and pensions age profiles, survival probabilities and so forth. For this reason, we have carried out robustness checks of our efficiency analysis with respect to the value of the risk-free position.

The second largest components of household wealth are the housing stock and the present value of rents. Their average value is of similar magnitude, but for individual households these two differ considerably over the life cycle. Younger households are typically under-housed, in the sense that their future needs are worth more than their current housing stock. Older households instead tend to be over-housed (with the notable exception of renters), because the present value of their future rents is reduced by the shortening time horizon, other things being equal.

8 The North West includes the three large industrial cities of Milan, Turin and Genoa; the North East many middle-sized cities and towns, such as Bologna, Venice, Verona, Trieste; the Centre includes the capital city, Rome, and many medium-sized towns such as Florence, Perugia and Ancona; finally, the South, which is largely rural, but includes Naples and Bari). The two large islands, Sicily and Sardinia, are also counted as South here.

9 De Roon et al. (2002) find that a similar result is also true for some areas in the US, but do not analyze the efficiency of US household portfolios. We also find evidence, available upon request, of significant beta hedge ratios on at least some financial assets in other European countries (France, Germany, Spain and the UK).

10 In the rest of the paper, we focus on those observations with valid records of financial assets and housing stock values and for which we have been able to derive an estimate of both human capital and the present value of rent. This occurs in 7457 cases out of 8011.

Table 3
Regression of excess return on housing on financial assets excess returns.

Variable	North West	North East	Centre	South
Constant	2.6378 (0.556)	2.8218 (0.591)	2.7910 (0.737)	2.8088 (0.565)
$r_{GOV.}$	−0.0128 (0.280)	0.0392 (0.297)	0.1190 (0.371)	−0.1461 (0.284)
r_{CORP}	−0.2757 (0.477)	−0.5013 (0.507)	−0.7619 (0.632)	−0.3794 (0.484)
r_{STOCKS}	−0.0968 (0.028)	−0.0427 (0.030)	−0.0844 (0.037)	−0.0232 (0.029)
p-value	0.001	0.030	0.015	0.012
R^2	0.523	0.350	0.390	0.405

Note: Standard errors in parentheses. Number of observations = 28.

Table 4
Amounts held in financial and real assets.

Asset	(1) Average	(2) Median	(3) Conditional avg.
Risk-free financial assets	12,728	5200	15,410
Government bonds	4885	0	14,136
Corporate bonds	2638	0	7632
Stocks	3232	0	9531
Total financial assets	23,482	7250	46,709
Fix-rate mortgages	1048	0	3033
Floating-rate mortgages	1299		1334
Other debt and mortgages	949	0	2745
Housing	132,853	100,000	204,110
Present value of rents	141,988	99,985	186,417
Human capital	485,872	366,224	651,173
Total wealth	496,924	368,242	708,282

Note: Number of observations in columns (1) and (2) = 7457; in column (3): 2577.

Even within financial assets, Table 4 reveals that the risk-free position accounts for the largest fraction, with an average of almost € 13,000 (the same is true if we look at the medians). The three risky assets account for an average of € 10,000 overall (their median holdings are instead zero, because participation is not sufficiently widespread). Debt positions are relatively small, even though mortgages are sometimes quite large (they exceed € 77,000 for 1% of the sample).

Column 3 of Table 4 presents average holdings for those households who have some financial risky assets or liabilities. The number of observations falls to just 2577; this is the relevant sample for most of our analysis. This sample is richer overall: average financial wealth is almost twice as high as in the full sample, with much larger values for risky financial assets (accounting for € 31,000 overall). Total wealth is also higher, but by a more modest 42%.

In our efficiency analysis, we treat fix-rate mortgages as negative holdings of government bonds (the only long-term bonds available are on government debt), floating-rate mortgages as negative positions on the risk-free asset and all other debt (including home-improvement mortgages) as negative holdings of corporate bonds (other debt typically has medium-term maturity like corporate bonds). Thus a household with risk-free assets and a fix-rate mortgage or other debt belongs to this "well diversified" group.

The distinction between households with at least some risky financial assets or liabilities and the remaining households is of particular relevance for us, because for the latter group the test statistic takes the same value for all households in the same broad region. In Table 5 we show how this classification changes according to the broad regions introduced earlier (see Tables 2 and 3).

We see that the highest proportion of risk-free financial asset portfolios (83.92%) is found in the South, the lowest in the North East (53.18%). This implies that the sample size for our efficiency test differs a lot from the total sample in its regional composition, with a much smaller fraction of households resident in the Southern regions (15.13% as opposed to 32.53%). However, the relative proportions of households resident in the three other macro regions is roughly in line with the full sample.

4. Optimal portfolio allocation and efficiency test results

The return data we have described in the previous section have clear-cut implications for optimal portfolio weights, according to Eq. (2). Moreover, they can be used to assess the efficiency of actual household portfolios, using the Gourieroux and Jouneau (1999) test.

4.1. Optimal portfolio allocations

The normative predictions of our model are best understood if we split the sample into three age groups and take average values of total wealth, human capital, gross housing wealth and net present value of rents (PVR) for each. For the sake of brevity we consider here only households who live in the North West region, as these typically have more diversified financial portfolios, and we concentrate on those that hold at least one risky asset.

We define the oldest group to include home-owners whose head is 70 years of age or over ($N = 137$); they are typically overhoused (their gross housing wealth is € 262,102 whilst their PVR is € 66,695), and have relatively low human capital (€ 237.166). The middle group consists of home-owners whose head is 50–69 years old ($N = 357$); they have positive net housing wealth (their gross housing wealth is € 252,416 whilst their PVR is € 157,427), and have relatively high human capital (€590,013). The youngest group includes home-owners whose head is under 50 ($N = 229$): their net housing is substantially negative, their human capital very large. We do not display results for renters ($N = 148$), because they are quite similar to this last group, even though their human capital wealth is even smaller.

Throughout Table 6 we consider the case where the relative risk aversion parameter is unity. In column 1 of Table 6 we show optimal portfolios for our model, which adopts a "net housing" concept and uses the estimated correlations between housing and financial assets returns. The optimal portfolios weights for bonds are relatively constant across age groups (around 12%); major differences

Table 5
Classification by region.

	Total		North West		North East		Centre		South	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%
Risk-free asset + housing	4880	65.44	1120	56.22	802	53.18	922	60.22	2036	83.92
Risk-free + risky assets/liabilities + housing	2577	34.56	872	43.78	706	46.82	609	39.78	390	16.08
Total assets	7457		1992		1508		1531		2426	

Table 6
Optimal portfolios by age for a unit relative risk aversion coefficient.

	(1) Estimated correlations net housing	(2) Zero correlations net housing	(3) Estimated correlations gross housing
Old – aged 70+			
Descriptive statistics: sample averages			
Total wealth	504,275	504,275	570,971
Human capital	237,166	237,166	237,166
Housing	262,102	262,102	262,102
PVR	−66,695	−66,695	0
Optimal portfolio weights			
Gov. bonds %	11.67%	12.06%	11.60%
Corp. bonds%	18.55%	6.63%	20.76%
Stocks %	4.14%	0.42%	4.83%
Optimal portfolio holdings for average wealth			
Gov. bonds	58,851	60,793	66,229
Corp. bonds	93,560	33,425	118,507
Stocks	20,881	2130	27,563
Young old – 50–69 of age			
Descriptive statistics: sample averages			
Total wealth	752,904	752,904	910,331
Human capital	590,013	590,013	590,013
Housing	252,416	252,416	252,416
PVR	−157,427	−157,427	0
Optimal portfolio weights			
Gov. bonds %	11.93%	12.06%	11.78%
Corp. bonds %	10.51%	6.63%	15.16%
Stocks %	1.63%	0.42%	3.08%
Optimal portfolio holdings for average wealth			
Gov. bonds	89,822	90,766	107,236
Corp. bonds	79,137	49,904	138,020
Stocks	12,295	3,179	28,067
Young – less than 50 years of age			
Descriptive statistics: sample averages			
Total wealth	968,367	968,367	1,286,754
Human capital	1,037,479	1,037,479	1,037,479
Housing	209,247	209,247	209,247
PVR	−318,387	−318,387	0
Optimal portfolio weights			
Gov. bonds %	12.17%	12.06%	11.89%
Corp. bonds %	3.16%	6.63%	11.63%
Stocks %	−0.66%	0.42%	1.98%
Optimal portfolio holdings for average wealth			
Gov. bonds	117,825	116,741	153,045
Corp. bonds	30,598	64,186	149,685
Stocks	−6384	4089	25,514

Note: This table shows descriptive statistics and optimal portfolio weights and holdings for different concepts of housing wealth (net of present value of rents or gross) and for different estimates of the partial correlation coefficients between housing and financial returns (as estimated and reported in Table 3, or zeros). All computations refer to the sample of home-owners who have at least one risky financial asset in their portfolios, and who live in the North West region.

occur instead for corporate bonds and stocks. For the older group, which is over-housed, corporate bonds should be 18.55% and stocks 4.14% of total wealth. In absolute terms, these households should on average invest little over € 20,000 in stocks. Their observed average stock holding is € 12,327. For the youngest group, instead, the optimal portfolio weight in corporate bonds is just 3.16%, whilst the weight for stocks is negative (−0.66%). These households should short stocks by € 6384 on average. Their observed average stock holding is instead positive at € 8418, but 40% of these households have zero stocks.

Column 2 presents optimal portfolios for the case where the correlation coefficients between housing and financial assets returns are all zero. This corresponds to Eq. (1) and generates Markowitz portfolio weights.

For comparability with column 1, we keep using our net housing definition. In this case, portfolio weights are constant across age groups. The weight on corporate bonds is 6.63%, much smaller than in column 1 for all but the youngest group. The optimal weight on stocks is positive but very close to zero (implying positive positions between € 2000 and € 4000, comparable to the average holdings reported in table 5).

Column 3 presents optimal portfolio weights for the case where housing is just an asset (as in this model when rent is uncorrelated with house prices). Households should invest more in corporate bonds and stocks compared to the case shown in column 1, and they should never take short positions in stocks. As in column 1 there is an age pattern in stocks, with the oldest investing more than the youngest, but the difference is relatively minor. This highlights the crucial role played by the PVR in generating sharply different prescriptions by age.

In Table 7 we present the Markowitz portfolios weights for higher values of relative risk aversion: all weights decline and the stock weight is as small as 0.14% when the coefficient of relative risk aversion is 3. We do not show the effects for columns 1 and 3, as they are easily worked out.

The results shown in Table 6 and 7 highlight the crucial role played by the liability aspect of housing in generating age effects on optimal portfolios: even in a model with no mean reversion

Table 7
Optimal Markowitz portfolios and risk aversion.

	Relative Risk Aversion			
	1 (%)	2 (%)	3 (%)	4 (%)
Portfolio weights				
Bonds	12.06	6.03	4.02	3.01
CB	6.63	3.31	2.21	1.66
Stocks	0.42	0.21	0.14	0.11

in stock returns, or estimation risk, we obtain that portfolio weights of stocks should depend on age. In particular, we find that stock holdings should increase with age.

We conjecture that this last prediction would be weakened if there was mean reversion in stock returns (see Campbell and Viceira (2002) for an appraisal); it would be strengthened if estimation risk was taken into account (given that estimation risk is highest for the young, see Barberis (2000)).

4.2. Efficiency test results

We compute the Gourieroux and Jouneau (1999) efficiency test described in Section 1 for all the 7457 household portfolios observed in our data. However, a distinction must be made between the 4880 households who report not having any risky financial assets or liabilities, and the 2577 who instead have at least one such asset or liability. For the former group, by construction the test statistic takes the same value for all households within the same macro-region, irrespective of the amount held in either asset.[11] For the latter group, instead, the test statistic varies across observations, depending on their risky asset shares.

It is worth stressing that the test statistic is based on the squared of the Sharpe ratio, thus portfolios with Sharpe ratios of the same magnitude but opposite sign are treated in the same way. In our discussion so far we have ignored this feature. In our analysis of diversified portfolios, we shall consider efficiency to be rejected when the test statistic either takes a value higher than the threshold or when the expected return of the hedge-adjusted portfolio is below the risk-free rate.

Table 8 reports test results for the sample of well-diversified portfolios, that is for households with some risky financial assets or liabilities. It does so for two different test sizes. In the upper portion of the table, the chosen test size is 5%; in the lower part, we have set it at 10%.

Depending on the chosen test size, we find that a fraction of 29–37% of observed portfolios are conditionally efficient overall. Nevertheless, there is much regional variability with the lowest proportion of portfolios in the North West that are considered efficient (18–27%).

This is partly due to differences in the partial correlations between housing returns and stocks highlighted in Table 3: as we have already pointed out, for both North West and Centre there are large, negative and significant coefficients on stocks. But it also reflects differences in financial investments across regions: as we know, households in the North West (and North East) have the highest investments in stocks. Depending on the housing position, these two factors together play a key role in explaining the efficiency or otherwise of North West and Centre household portfolios.

It is useful to see how these proportions vary with net housing wealth. We therefore split the sample into three groups, according to net housing wealth (P_0D_0 in Eq. (2)). We find that roughly a third of the observations lies to the left of € −50,000, roughly a third to the right of € 50,000, and the remaining third in between. These proportions are stable across regions, with the only exception of the South where relatively more observations fall in the middle, and fewer lie to the left of € −50,000. Our analysis implies that portfolios of the over-housed should have more in stocks than the Markowitz portfolio, and particularly so in the North West and Centre. We find that the proportion of portfolios exceeding 2% in stocks is indeed higher for the over-housed in the North East (63%) and South (36%), but close to the average in the North West and Centre.

On the basis of this qualitative analysis, we could conclude that many of the over-housed who invest more than 2% in stocks could have efficient portfolios, but we need a formal test to support this conjecture. It is in fact worth stressing that the larger the positive net-housing position the larger the share North West in stocks should be. Given that financial wealth is a relatively small component of total wealth, households with a large, positive net-housing position may well require large investment in stocks to be efficient.

In Table 9 we present the number and fraction of efficient portfolios in each of these three groups (with positive, negligible and negative housing wealth) by broad region. For the sake of simplicity, we report them for just one test size (5%).

We see from the last row of Table 9 that 954 well-diversified households have efficient portfolios, that is 37% of the total. As we have also seen in Table 8, this proportion is highest in the North East and Centre (43–44%), lowest in the North West (27%). We also see that the highest proportion of efficient portfolios (60%) obtains among households who are "under-housed", that is whose net-housing position is below € −50,000. This group includes tenants as well as young home-owners. The lowest proportion (7%) is found among those who are "over-housed" (net housing is larger than € 50,000). Among those with intermediate positions ("negligible") the proportion of efficient portfolios are intermediate, but higher than the overall group average. Thus most of the interesting deviations from the overall average are to be found among those with positive net housing wealth, and in the broad North West region.

When we focus on North West households by housing wealth, we find a different pattern: the overall average of 27% masks a low proportion of efficient portfolios (10%) among the positive housing wealth positions, and a much higher one (42%) among those whose housing position is close to zero. In comparison to other regions, North West over-housed households are more often efficient, the under-housed are less often efficient.

The efficiency pattern is similar to the national average for North East and Centre, albeit with fewer over-housed portfolios classified as efficient. In the South we find a very large fraction of under-housed portfolios efficient. This can be explained by the combination of two factors: the test statistic is very low in the South for no risky financial assets portfolios, and even those South households who invest in risky financial assets have relatively small positions in these assets.[12]

[11] For instance, for all 1049 households who live in the North West and have no risky assets, the test statistic takes a value of 6.34. Under the null of efficiency, this is distributed as a chi-squared random variable with 2 degrees of freedom. The corresponding critical values are 4.60 (test size: 10%) and 5.99 (test size: 5%). Thus the test always rejects. For the North East, the calculated statistics is 2.39, for Centre it is 4.30, 0.41 for households who live in the South, and therefore all these portfolios are efficient for any sensible test size.

[12] We checked whether these differences are statistically significant by running a probit regression of the efficiency test outcome on the interactions between housing wealth dummies and broad region dummies, taking as the control group the negligible wealth group in Centre. We find strong negative effects for most terms, particularly those involving the North West and the South, with markedly different coefficients across North West variables. We can therefore conclude that the evidence shown in Table 9 is strong despite the relatively small cell sizes.

Table 8
Test results for all households with risky financial assets.

	Whole country (N = 2572)		NW (N = 871)		NE (N = 703)		Centre (N = 608)		South (N = 390)	
	N	%	N	%	N	%	N	%	N	%
Test size = 5%										
Inefficient	1623	62.98	636	72.94	405	57.37	344	56.49	238	61.03
Efficient	954	37.02	236	27.06	301	42.63	265	43.51	152	38.97
Test size = 10%										
Inefficient	1820	70.62	714	81.88	448	63.46	412	67.65	246	63.08
Efficient	757	29.38	158	18.12	258	36.54	197	32.35	144	36.92

Table 9
Proportion of efficient portfolios (test size = 5%) by net-housing position.

	Whole country		North West		North East		Centre		South	
	N	%	N	%	N	%	N	%	N	%
Over-housed	67	7.20	30	10.00	16	5.97	13	5.78	8	5.80
Negligible	388	47.67	107	41.80	114	52.78	93	53.14	74	44.31
Under-housed	499	59.98	99	31.33	171	77.03	159	76.08	70	82.35
All	954	37.02	236	27.06	301	42.63	265	43.51	152	38.97

How important is inefficiency in terms of risk-adjusted returns? After taking out the hedge term, we compute Sharpe ratios for the efficient and for the inefficient. The overall average Sharpe ratio for the efficient is 0.61, it is −0.15 for the inefficient (who are mostly below the risk-free rate). The Sharpe ratios difference is highest for the over-housed, lowest for the under-housed. One way to evaluate the importance of our findings is to do back-of-the-envelope calculations on the long-term consequences of inefficiency for the over-housed. For this group, inefficiency brings about a loss of 90 basis points for 1% standard deviation. Over a 20-year time horizon, for every percentage point of risk taken, on average this group loses 20% of final wealth by failing to hedge housing.

We have checked whether our results depend on the ad hoc simplifying assumptions made on human capital, particularly on the rate used to discount future earnings and pension benefits, and on its risk-free nature. When we increase the discount rate for human capital by a third, the efficiency test results are only marginally affected. When we take the self-employed out of the analysis, the patterns highlighted above remain valid.

5. Robustness analysis

In Section 3 we presented results based on a number of assumptions, some of which we can relax. In this section, we show how our results are affected when we:

(a) allow human capital to be risky for working-age households;
(b) assume less than unit correlation between the housing service price (rent) changes and house price changes, i.e. owning is less than a perfect hedge against rent risk;
(c) allow households to invest in foreign as well as domestic assets;
(d) allow for non-negativity constraints;
(e) consider a range of different parameter estimates of the stock exchange parameter in the housing return equation.

5.1. Risky human capital

Our theoretical and empirical analysis has so far treated human capital returns as risk-free. This assumption is of course very strong, but it can be relaxed if we are prepared to treat human capital risky like housing wealth,[13] that is given in the short run. In this case our conditional analysis requires conditioning on two assets, and Eq. (2) becomes

$$\underline{X}_0^{*T} = \left[\frac{-\frac{\partial V}{\partial TW}}{\frac{\partial^2 V}{\partial TW^2}}\right]\Sigma^{-1}\underline{\mu}^T - P_0 D_0 \Sigma^{-1}\Gamma_{bP}^T - HC_0\Sigma^{-1}\Gamma_{bHC}^T \quad (3)$$

where HC_0 is the current value of human capital and Γ_{bHC}^T denotes the vector of covariances between human capital return and financial assets. The intuition behind Eq. (3) is straightforward: optimal portfolios are made of the Markowitz portfolio, net of two hedge terms, one for housing, the other one for human capital.

The more difficult task is to find good estimates of human capital returns. In principle, one should use panel data spanning a long period and recording hourly wages at a suitable frequency (semi-annual or higher). To our knowledge, such data do not exist for Italy (SHIW has a small panel component, but the survey takes places at 2–3 years intervals). Given the exploratory nature of this robustness exercise, we decided to use aggregate data on earnings per employee, and to remove the effects of work-force aging by taking the residuals of semi-annual changes in the logarithm of earnings per employee on a deterministic trend.

The resulting annual excess return has a negative sample mean (−0.6%) and a relatively low standard deviation (2.43%). It exhibits negative correlations with all three financial assets: −.21 with Government Bonds, −.17 with stocks and −.01 with corporate bonds. Its correlation with housing is positive (.61), even though this is irrelevant for our analysis. The regression of human capital return on a constant and the three financial asset returns produces the following estimates:

$$r_t^{HC} = \underset{(0.29)}{0.614} - \underset{(0.14)}{0.425 r_t^G} + \underset{(0.25)}{0.450 r_t^C} - \underset{(0.01)}{0.025 r_t^S} \quad (4)$$

There is a strong negative relation with Government Bonds, positive with Corporate Bonds, and a smaller, but marginally significant, negative relation with stocks.

Eq. (4) provides both the weights of the second hedge portfolio in (3), and the discount rate to be used to compute, for each household, an estimate of HC. Based on sample means of the three finan-

[13] For issues related to portfolio choice and risky human capital, see Heaton and Lucas (2000) and Baptista (2008).

cial asset returns, and the observed risk-free rate at the end of 2002, we can compute the nominal return implied by the model. Once we subtract 1.5% inflation, we obtain a real annual discount rate of 1.39%. We apply this discount rate to all labor income, including self-employment income, but note that this may bias HC upwards for the self-employed (whose income may be riskier than earnings). We treat HC as risk-free for the retired (that is, for all households whose head is 60 or more), given that pension income is price inflation-index in Italy.

In Table 10 – which compares directly to Table 4 – we show the average, median and conditional average of the new human capital variable, as well as of total financial assets and total wealth. Even though human capital has been reduced by some 10% on average, it remains by far the largest component of total wealth. In the more interesting case of households owning some financial risky asset (column 3), we find that human capital is smaller than housing in 349 cases (one in seven), it is smaller than net housing wealth in just 187 cases (one in thirteen): these households tend to be older than the rest of the sample (on average by 10 and 15 years, respectively).

In Table 11 we show how many portfolios are efficient by region and net-housing position – the table compares directly to Table 6 in Section 3. When we look at the country as a whole, we notice a much lower number of efficient portfolios (529 instead of 954). This is also true for the under-housed (272 instead of 499) and for those with negligible housing position (178 instead of 388). The over-housed, instead, appear more often efficient (99 instead of 67).

To understand these patterns, we note that the presence of the human capital hedge shown in Eq. (3) implies that households with negligible housing positions should increase their shares of government bonds and (to a lesser extent) stocks, and decrease their share of corporate bonds. Given that the tangency portfolio already has a very large share of government bonds, investing even more in such bonds may be hard. Also, the relatively small coefficient on shares has to be compared the similarly small share of stocks in the tangency portfolio (2%). Given that few households have large stock positions, the overall fall in efficiency comes as no surprise.

The reason why efficiency decreases most for the under-housed, least for the over-housed, is because the under-housed are young and therefore have more human capital: they should increase Government Bond holdings most, and avoid (fixed-interest) mortgages. The over-housed, instead, have lower human capital, little or no mortgages, and have higher holdings of Government Bonds and Stocks. To the extent that our measure of human capital risk is appropriate for them, they tend to do the right thing more often than the under-housed.

We should stress that these results are not driven by the low return on human capital implied by Eq. (4). Even if we assume human capital return to be much higher (4%), and discount future incomes accordingly, we find that the number of efficient portfolios is largely the same as shown in Table 11.

We conclude from this analysis that the risky nature of human capital may have important consequences for portfolio efficiency.

Table 10
Amounts held in financial and real assets when human capital is risky.

Asset	(1) Average	(2) Median	(3) Conditional avg.
Total financial assets	23,482	7250	46,709
Housing	132,853	100,000	204,110
Present value of rents	141,988	99,985	186,417
Human capital	436,413	333,611	579,850
Total wealth	447,465	337,278	663,960

Note: number of observations in columns (1) and (2) = 7457; in column (3): 2577.

5.2. Owning is a less than perfect hedge against rent risk

In Section 3 we have considered the case where owning is a perfect hedge against rent risk, because the price of housing services has unit correlation with house prices. This case is appealing in the long run (when rents are roughly proportional to house values), but is obviously not necessarily true in the short or even medium run. Here we consider what happens to our efficiency analysis when the correlation between house price changes and rental price changes is not perfect, but varies between one (as in Section 3) and zero. This last case is analyzed in some recent papers that ignore the liability side of housing (Flavin and Yamashita, 2002; Cocco, 2005; Pelizzon and Weber, 2008).

Fig. 1 shows the proportions of efficient portfolios for the three net-housing groups considered so far as a function of $\beta_{P\pi}$, the hedge ratio between house returns and rents. We should stress that we keep the groups' composition constant in this comparison, even though their net housing value (defined as value of the house minus $\beta_{P\pi}$ times the present value of rents) changes. In other terms, net-housing positions are defined once and for all with reference to the case where $\beta_{P\pi} = 1$.

We see from Fig. 1 that the over-housed appear mostly inefficient for any beta. This is not surprising: the reason why they are inefficient for $\beta_{P\pi} = 1$ is that they do not hedge their positive housing position. Taking lower values of beta implies even larger positive housing positions, and efficiency is even less often achieved.

Efficiency results also deteriorate going from right to left for the other two groups, whose net-housing position becomes less negative and then positive when beta approaches zero, as long as they own at all. For renters instead net housing never becomes positive, and when $\beta_{P\pi} = 0$ the analysis collapses to the standard efficiency analysis of financial portfolios.

Housing wealth plays a role for all three groups and this explains why the lines do not appear to converge as $\beta_{P\pi}$ approaches zero.

Overall the analysis shows that housing needs plays an important role for portfolio efficiency and ignoring this aspect induces an over-estimation of portfolio inefficiency.

5.3. International portfolio diversification

In Section 3 we have assumed that Italian households invest in domestic stocks and bonds. This is particularly problematic for indirect holdings of stocks. We know from financial industry sources (Assogestioni) that in 2002 Italian mutual funds stock investment were three-quarters in foreign stocks, one quarter in domestic stocks. According to a different source, the Bank of Italy financial statistics, roughly 50% of stocks were from Euro-area markets. Finally, we know that direct and indirect stock market participation were similar in 2002, and this is also true for average amounts in our sample. Direct holdings are almost exclusively concentrated in domestic stocks.

Based on this information, we checked whether our analysis is robust to assuming that stock holdings were split among domestic stocks (62%) and foreign stocks (32%), and used MSCI Italy and MSCI world returns to compute their returns. We denote this asset as ‘‘international stocks''.

In Tables 12 and 13 we report descriptive statistics of the resulting returns. Compared to Table 1, we see from Table 12 that international stocks have lower expected returns (3.96% versus 4.90%) and lower standard deviation (27.65% instead of 28.99%). Remarkably, they have a negative correlation with government bonds return: this insurance property implies that optimal stock holdings are higher than in the case previously considered.

The efficiency portfolio has weights of .67 on government bonds, .29 on corporate bonds and .04 on stocks; this compare to

Table 11
Proportion of efficient portfolios by net-housing position when human capital is risky for workers (test size = 5%).

	Whole country		North West		North East		Centre		South	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%
Over-housed	99	10.65	30	10.00	26	9.74	23	10.22	20	14.49
Negligible	272	33.41	88	34.51	59	27.57	54	30.86	71	42.26
Under-housed	178	21.39	57	17.98	40	18.18	52	15.61	29	34.12
All	529	20.52	175	20.07	125	17.83	109	18.02	120	30.69

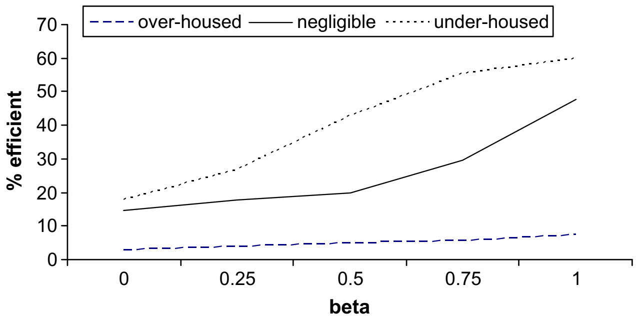

Fig. 1. Proportions of efficient portfolios and the hedge ratio between house price and rent.

Table 12
Sample first and second moments of annual excess returns.

	Government bonds	Corporate bonds	International stocks
Expected return %	4.0981	2.2845	3.9649
Standard deviation %	5.2383	3.2169	27.6519
Correlation			
Government bonds	1	0.8404	−0.0981
Corporate bonds		1	0.0565
International stocks			1

Table 13
Correlation matrix of housing and financial returns.

	North West	North East	Centre	South
Government bonds	−0.0164	−0.1169	−0.1161	−0.2036
Corporate bonds	−0.0843	−0.1691	−0.2177	−0.1998
International stocks	−0.5432	−0.3660	−0.4484	−0.1959

.63, .35 and .02 of the domestic stock return case. Table 13 however shows that correlation coefficients with housing are quite similar, and this results in minor changes in the regression coefficients (see Table 14).

In Table 15 we present the number and fraction of efficient portfolios in each net-housing group by broad region. A comparison with Table 8 shows that there are remarkably few differences.

5.4. Non-negativity constraints

Our analysis neglects the issue of short-selling constraints: in our model, households can take negative positions on stocks, and their housing-related liabilities can exceed the value of their housing stock. If actual households are subject to non-negativity constraints on stocks, and if their net positions on bonds cannot exceed their housing value, then their feasible efficiency frontier will lie below the frontier we have considered. This may imply that some portfolios that we consider inefficient are instead efficient.

This issue is of particular concern in our case, where we analyze conditional efficiency, because the hedge term in Eq. (2) may imply that the optimal portfolio itself violates these constraints. For those households whose optimal portfolio violates non-negativity constraints our analysis should not be applied.

Let us re-write Eq. (2) in portfolio share terms:

$$\frac{X_0^{*T}}{TW} = \left[\frac{-\frac{\partial J}{\partial TW}}{\frac{\partial^2 J}{\partial TW^2}}\right]\frac{1}{TW}\Sigma^{-1}\underline{\mu}^T - P_0 D_0 \Sigma^{-1}\Gamma_{bP}^T$$
$$= \alpha\Sigma^{-1}\underline{\mu}^T - P_0 D_0 \Sigma^{-1}\Gamma_{bP}^T \qquad (5)$$

where α is one over the relative risk aversion parameter. In this context, the optimal portfolio depends on risk aversion. If we are prepared to assume that relative risk aversion takes a unit value (as in the standard log utility case), then we can derive the optimal portfolio for each value of the net-housing position, and find out for which households negativity constraints are violated.

We find that, in total, 908 households have optimal portfolios that violate non-negativity constraints (when $\alpha = 1$): 379 in the North West, 215 in the Centre, 257 in the North East and just 57 in the South. Almost all these households (752 of 908) are under-housed. This is not surprising, because the under-housed should hedge their net housing risk by holding negative positions on stocks, as shown in Table 6.

Given that the under-housed hold the largest fraction of efficient portfolios (almost 60%) even when we neglect the non-negativity constraints, we conclude that this type of constraints is not responsible for the common occurrence of inefficient portfolios.

5.5. Sensitivity analysis

The hedge term parameters in Eq. (2) are based on estimated parameters of the regressions of excess return on housing on financial assets excess returns for each macro region, and are shown in Table 3. The test procedure takes into account sampling variability in these estimates, but still uses the specific estimated values. The fact that the sample period is relatively short, and the sampling frequency is low, implies that the estimated parameters have large confidence intervals.

Unfortunately these confidence intervals cannot be narrowed easily, because of data limitations. The low frequency is dictated by the workings of the housing market, where volumes are sufficiently high twice a year (Spring and Autumn). The relatively short period is instead due to the relatively recent introduction of government bonds in Italy.

What we can do is to check how our efficiency analysis would change if the parameters were at the extremes of their confidence interval. Given the key role played by stocks, we shall concentrate on this particular parameter, keeping all remaining parameters at their point estimates.

In Table 16 we show the number of efficient portfolios for three macro-regions (the fourth, South, is almost completely unaffected) when we perturbate the stock coefficient: for each region, we consider the point estimate (Centre), the upper bound of the 95% con-

Table 14
Regression of excess return on housing on financial assets excess returns.

Variable	North West	North East	Centre	South
Constant	2.7403 (0.5259)	2.894 (0.5618)	2.8884 (0.7110)	2.8548 (0.5534)
$r_{GOV.}$	−0.0739 (0.2666)	−0.0289 (0.2840)	0.0536 (0.3595)	−0.1929 (0.2798)
r_{CORP}	−0.2896 (0.4454)	−0.4414 (0.4758)	−0.7547 (0.6021)	−0.3313 (0.4686)
r_{STOCKS}	−0.1146 (0.0284)	−0.0678 (0.0304)	−0.1049 (0.0384)	−0.0409 (0.0299)
p-value	0.000	0.009	0.006	0.007
R^2	0.576	0.416	0.436	0.433

Note: Standard errors in parentheses. Number of observations = 28.

Table 15
Proportion of efficient portfolios (test size 5%) by net-housing position.

	Whole country		North West		North East		Centre		South	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%
Over-housed	56.00	6.01	28.00	9.27	14.00	5.22	8.00	3.57	6.00	4.35
Negligible	372.00	45.76	102.00	39.84	104.00	48.60	96.00	54.86	70.00	41.67
Under-housed	525.00	62.50	126.00	39.50	166.00	74.11	164.00	77.36	69.00	81.18
All	953.00	36.87	256.00	29.19	284.00	40.23	268.00	43.86	152.00	38.87

Table 16
Proportion of efficient portfolios (test size 5%) by net-housing position, for different values of the stock coefficient.

	North West (*N* = 871)			North East (*N* = 703)			Centre (*N* = 608)		
Coefficient on stock	−0.0419	−0.0968	−0.1517	0.0152	−0.0427	−0.1015	−0.0111	−0.0844	−0.1577
Over-housed	47	30	29	22	16	28	21	13	7
Negligible	132	107	87	127	114	72	95	93	75
Under-housed	227	99	30	189	171	97	173	159	35
All	406	236	146	338	301	206	305	265	117

fidence interval (left), and the lower bound of the 95% confidence interval (right). The middle column corresponds to Table 7.

In the case of the North West, the highest value taken by the coefficient is negative but about one-half in absolute value than the point estimate. The number of efficient portfolios is much higher (406 instead of 236), and this increase is mostly accounted for by the under-housed. When we consider the lowest possible value of the coefficient, results are reversed: only 146 portfolios are efficient, and only 30 among the under-housed. The number of efficient portfolios among the over-housed is consistently low for all three values of the parameter.

In the case of the North East, the stock coefficient is sufficiently close to zero that the confidence interval crosses the zero line. So the highest value we consider is positive, while the lowest is negative and close in size to the point estimate for the North West. The number of efficient portfolios is very close between the first two columns, while the right column produces a pattern of efficiency quite close to the North West mid-range case.

In the last three columns, we show the number of efficient portfolios in the Center macro-region. In this case, all three values of the coefficient are negative, but the difference between the middle and the left column is relatively minor. The right column, corresponding to a very low value of the coefficient, shows a marked decline in the number of efficient portfolios (only negligible positions appear efficient).

Overall we have that the number of efficient portfolios changes if we allow the stock coefficient to takes values at the boundary of its confidence interval, but the qualitative result that efficiency is largely driven by net-housing positions is not affected.

6. Conclusions

In this paper we have investigated how portfolio choices should be taken when housing represents a perfect hedge for rent risk. We have argued that, in this case, future rents are a stochastic liability. In this asset-liability framework the relevant housing wealth concept is the difference between the market value of housing stock owned and the present discounted value of current and future housing needs. Under the assumption that main residence housing consumption equals housing needs, the present value of housing needs can be calculated from micro data on rents (actual for tenants, imputed or self-assessed for owner-occupiers).

According to our model, households are short on housing ("under-housed") when they either rent or own dwellings that are small compared to their future needs. Households who are owner occupiers may be long on housing ("over-housed") at a late stage in the life cycle, when their future housing needs are declining and their death probability is increasing. However, long positions can also be obtained by purchasing secondary or investment homes. The under-housed are more exposed to rent risk, the over-housed (who are interested in the liquidation value of their home) to house price risk.

In order to evaluate the empirical relevance of housing risk in household portfolios, we have shown how optimal portfolios should be when housing returns correlate with financial returns as they do in Italy, and compared the efficiency of financial asset allocations for Italian households who are over-housed, under-housed or who have negligible housing positions. This comparison is of particular interest for financial intermediaries who design and sell securities to the general public, but is also of interest for its economic and policy implications.

Our key result is that many households do not appear to hedge housing risk in a satisfactory way. We have shown that the largest fraction of efficient financial portfolios is found among households who are "under-housed", and should have less in stocks than the standard Markowitz portfolio. The smallest fraction of efficient portfolios obtains among households who are "over-housed". Even though in this group there is the highest proportion of stock-owners, their investment in stocks is often not sufficient to hedge all the housing risk.

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