

Pricing of Reverse Mortgages through Machine Learning: new opportunities for the actuaries

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Agenda

- What is The Reverse Mortgages?
- Reverse Mortgages: Why?
- Potential for Reverse Mortgages in Italy
- Aim of the research
- Risk Evaluation and Pricing Model
- Pricing of Reverse Mortgages through Artificial Neural Network
- Numerical application
- Italian Reverse Mortgage: financial or actuarial product?
- Reverse Mortgages: the role of the actuaries



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What is the Reverse Mortgages?

- It is a loan designed for the elderly against the home value, such that the value of the loan cannot exceed the present value of the liquidation value of the property at predicted death
- It is not a property transfer!
- It has a Non Negative Equity Guarantee.



What is the Reverse Mortgage?

- The house owner may use the home equity value to get a loan in the form of a lump sum or an annuity without selling the house.
- The loaned lump sum or income stream needs to be proportioned to the expected liquidation value of the home at borrower's death.
- The property sale proceeds are used to pay back the loan as well as the accumulated interest, while the remainder is up to the heirs.
- The total final payment is no more than the sale value of the mortgaged property.



RM's Markets

- RM were introduced in the USA in 1987 as Home Equity Conversion Mortgages – in 2007 strong consolidated market
- UK, Ireland and Spain, have developed more significant markets
- In Germany, Italy, France, Belgium and Sweden, RM's markets have not yet been well developed (Fornero 2012).
- In Italy, RM's were formally introduced in 2005 under the name *prestito vitalizio ipotecario*, available to the over 65 whose housing equity exceeds €70,000.



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Reverse Mortgages: Why?

- Reverse mortgages “as complementary or supplementary pensions savings” (EIOPA (2016))
- Tool to protect a wide range of “home rich and cash poor” elderly people facing increasing demographic trends
- Opportunity to transform an illiquid asset in liquidity, mainly for consumption purposes or for paying Long-Term Care expenses

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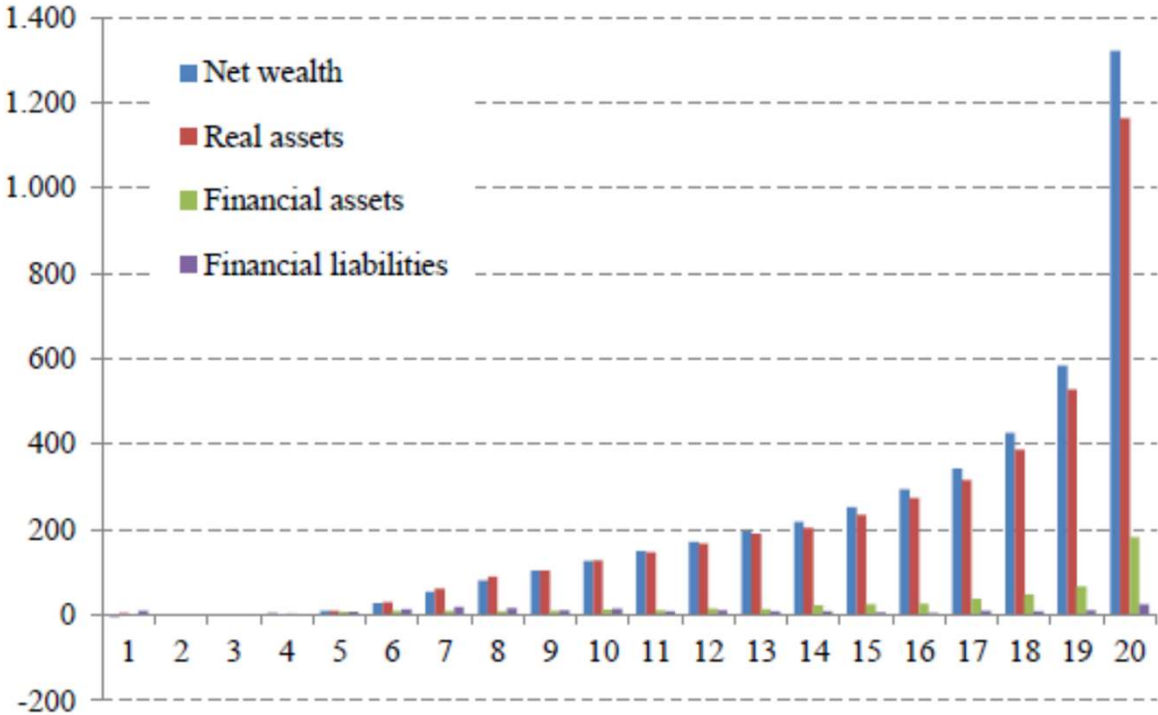
Potential for Reverse Mortgages in Italy

- Because of the demographic trends, the saving behaviour of the elderly are central to the policy debate
- Italy has very high homeownership rates (around 78% among the elderly)
- Italian households hold most of their wealth locked up in housing
- House-Rich Cash- Poor: about 30% of elderly belonging to the minimum income group owns a house that worths more than 200000 euros



Potential for Reverse Mortgages in Italy

Mean net wealth and its components
(quantiles of net wealth; thousands of euros)

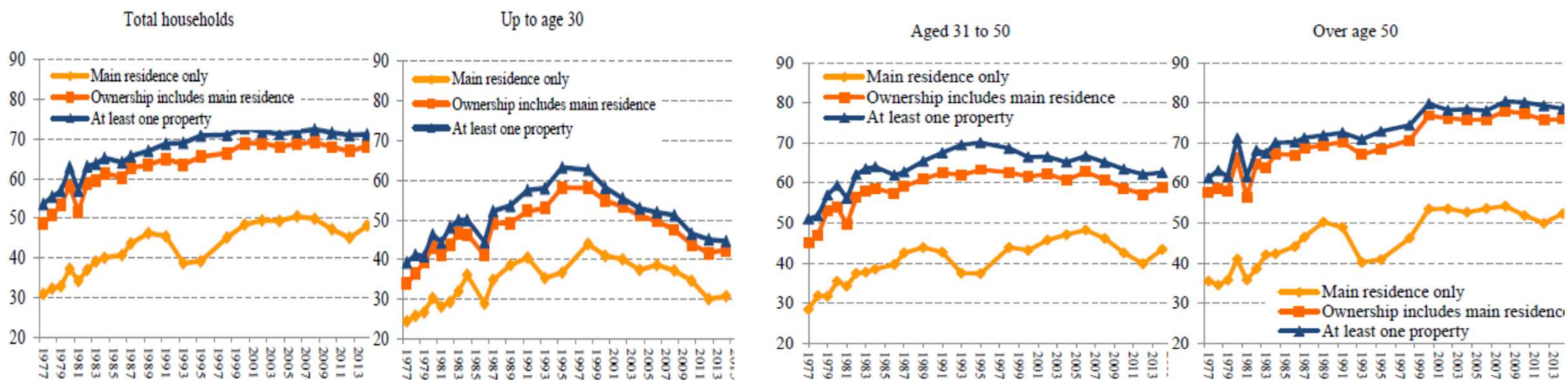


Source: Bank of Italy Survey on Household Income and Wealth 2016



Potential for Reverse Mortgages in Italy

Household ownership of real estate
by age group of head of household
(per cent)



Source: Bank of Italy Survey on Household Income and Wealth 2016



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Aim of the research

- Quantify the maximum present value of the lump sum or the recurring payments A that the insurer can provide to insured at the inception of the contract
- Value the RM under an actuarial perspective, considering the interaction of the risk factors, *house price risk*, *interest rate risk* and *longevity risk*.
- From the perspective of big data analytics, study the impact of various factors to forecast the liquidation house value in order to pricing RM at the inception of the contract



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Risk Evaluation and Pricing Formula

- *Longevity Risk*: an increase in life expectancy produces an higher exposure to volatility in house price and financial market.
- *House Price Risk*: volatility in real estate market
- *Financial Risk*: volatility in financial markets



Risk Evaluation and Pricing Formula

$$i_0(t-1, t) = \frac{i(t-1, t) - r_0^{RM}(t-1, t)}{1 + r_0^{RM}(t-1, t)}$$

$$r_0(t-1, t) = \frac{r_0^{HV}(t-1, t) - r_0^{RM}(t-1, t)}{1 + r_0^{RM}(t-1, t)}$$

r^{HV} is the house appreciation rate

r^{RM} is the reverse mortgage rate

i is the loan interest rate

Risk Evaluation and Pricing Formula

$$A = \sum_{t=1}^{\omega} t_{-1/q_x} \alpha HV_0 \min \left\{ \left[\prod_{k=1}^t 1 + r_0(k-1, k) \right]; \left[\prod_{k=1}^t 1 + i_0(k-1, k) \right] \right\}$$

α is the proportion of house value due to the insurer

HV_0 is the home value at the issue time

t_{-1/q_x} is the probability that the insured aged x at the issue time dies between ages $x+t-1$ and $x+t$

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Pricing of Reverse Mortgages through Neural Network

- The crucial point in the RM evaluation is the House price forecasting
- It depends on a wide number of variables, according to the geo-economic context.
- Artificial Neural Network (ANN) methodology provides a flexible computational framework in the case of highly complex systems and huge information set and allows to overcome the complex functional form that involves the most relevant variables, in most cases characterized by nonlinear relationships.



Pricing of Reverse Mortgages through Neural Network

- The model uses historical market performance data sets to train the artificial neural networks in order to predict future performances.
- The training is supervised: we present to the machine some input variables affecting the output, i.e. the historic house price, and the numerical algorithm finds the relations between them
- Once the connections between observed input and output are designed, the same patterns are used to forecast the house price.

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Numerical Application

Data: “*Housing in London 2018*” collected by the Greater London Authority City Hall

Output variable: Average House Price (AHP) 1997-2006.

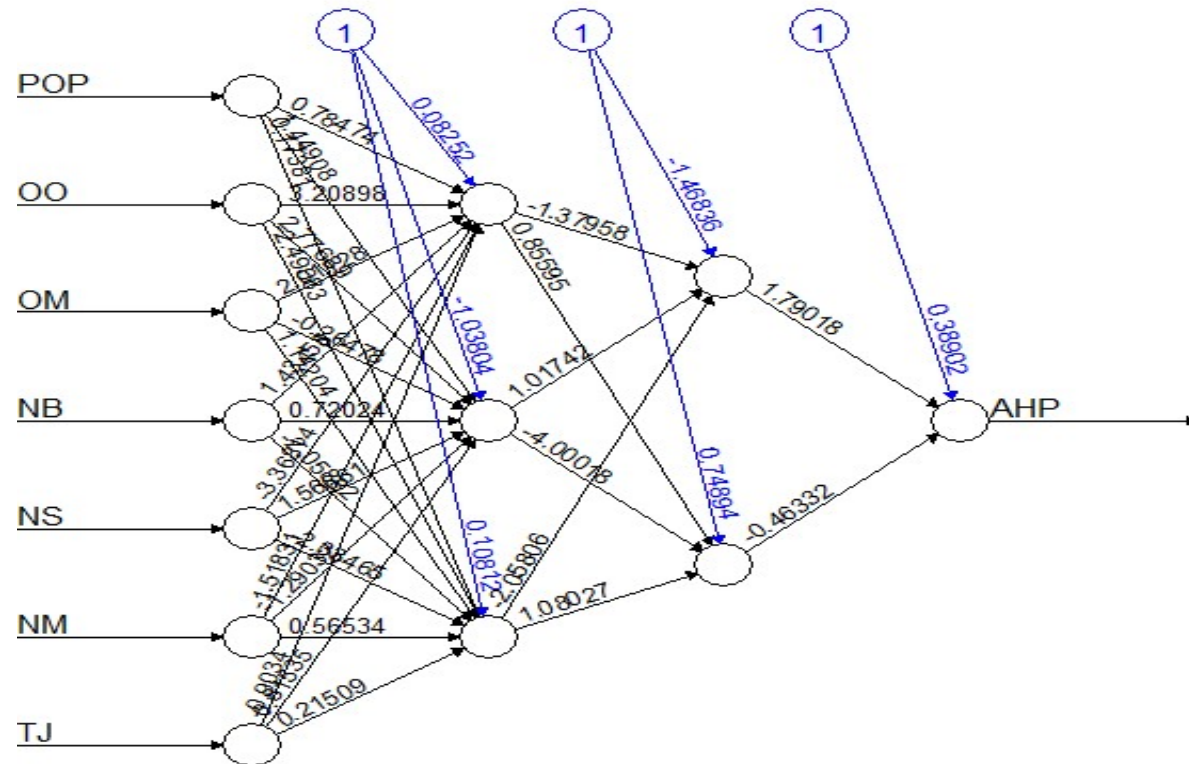
Input variables 1997 -2006:

- POP: historic London population
- OO: annual trend in household tenure – Owned outright
- OM: annual trend in household tenure – Owned with mortgage
- NB: New build homes
- NS: Net housing supply
- NM: Net migration (domestic and international)
- TJ: Trend of jobs in London

Longevity risk: Lee Carter model on the UK male mortality dataset projected 20 years ahead.

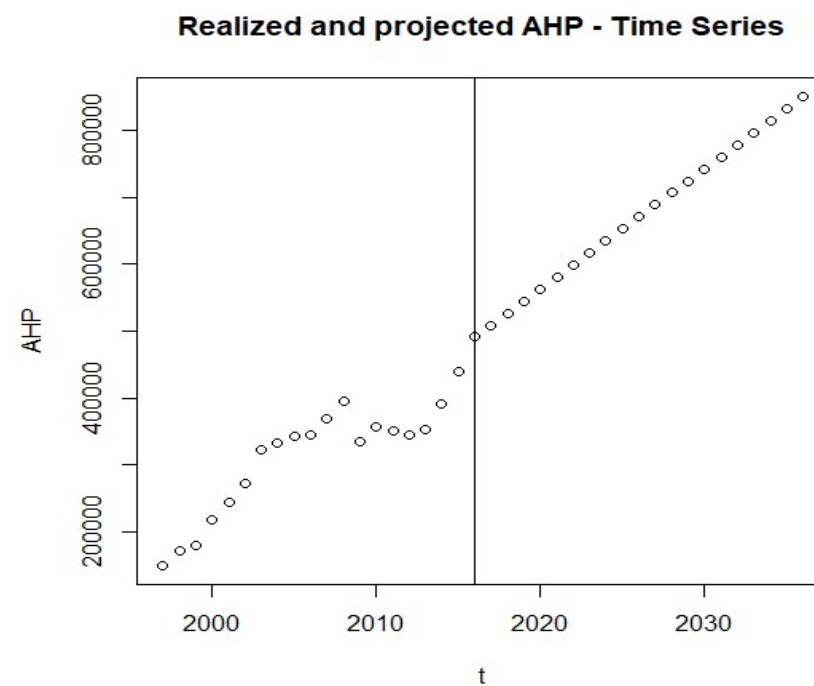
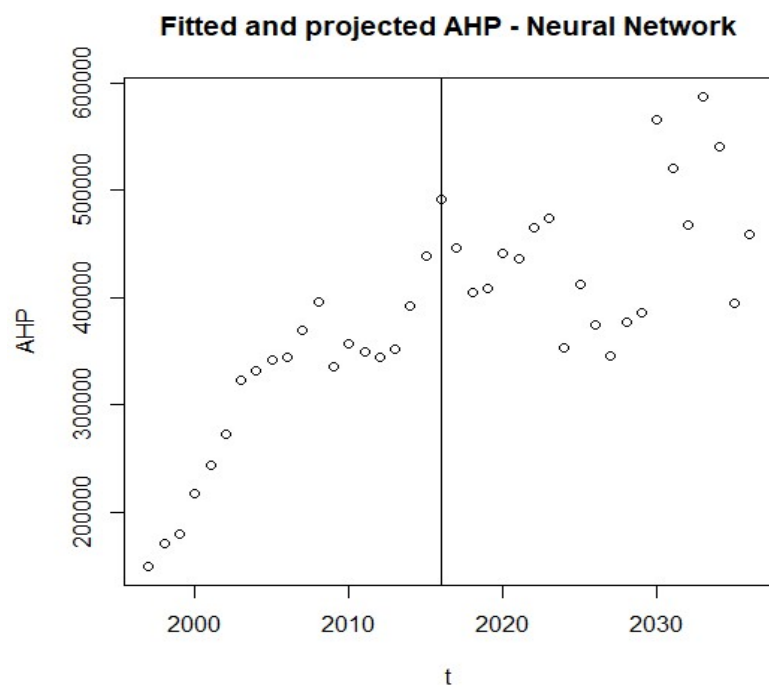


Numerical Application



Error: 0.028471 Steps: 77

Numerical Application



Numerical Application

The lump sum A is calculated in correspondence with the house price forecasted through NN and ARIMA time series (TS)

Hypothesis:

House owner	Aged 80
HP_0	200000
h	20
r^{RM}	5%
i	1,5%

Results:

α	NN	TS
0,5	71242,08	71242,08
0,6	85490,5	85490,5
0,7	99388,16	99738,91
0,8	109697,5	113987,3
0,9	117861,2	128235,7
1	121455,6	142484,2

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Italian Reverse Mortgage: financial or actuarial product?

- It is negotiated as a pure financial product
- Example: PVI Prestisenior MPS .
- The tables show the amount of the loan in percentage of the home value, for a single or a couple, at different ages
- If the product is valued under an actuarial perspective, it could appear more interesting!

60	16,3%	15,3%
61	17,0%	16,0%
62	17,7%	16,6%
63	18,5%	17,4%
64	19,3%	18,1%
65	20,1%	18,9%
66	21,0%	19,7%
67	21,9%	20,6%
68	22,8%	21,5%
69	23,8%	22,4%
70	24,8%	23,4%
71	25,9%	24,4%
72	27,0%	25,4%
73	28,1%	26,5%
74	29,3%	27,6%
75	30,5%	28,8%

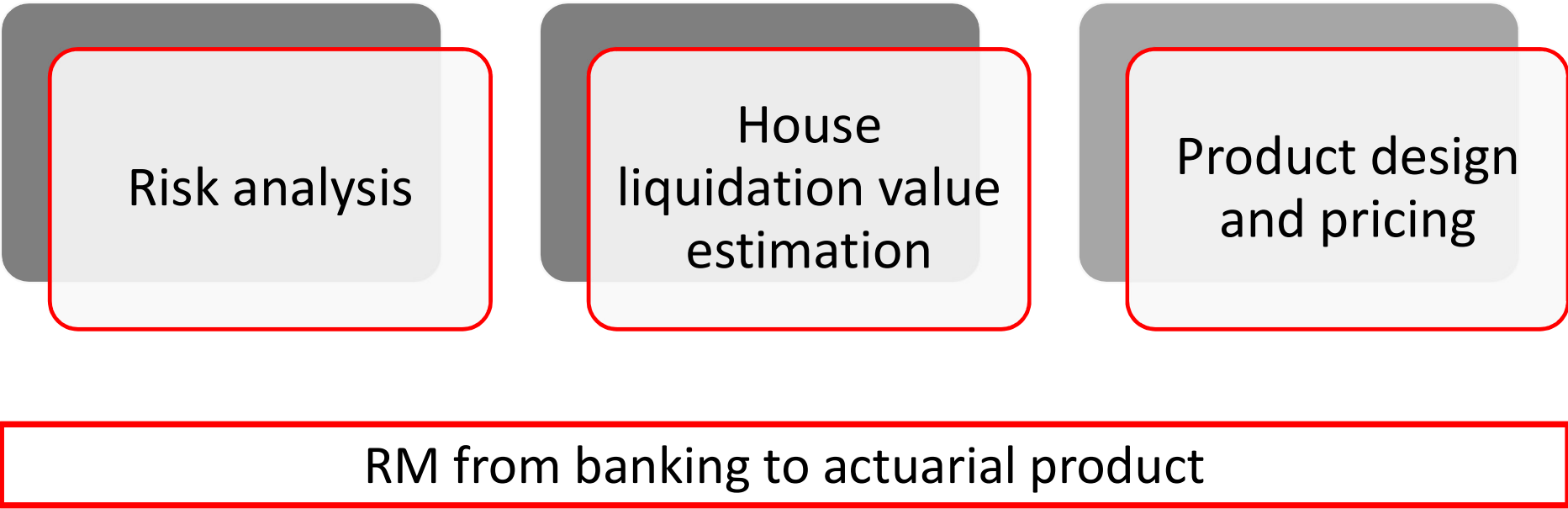
76	31,8%	29,9%
77	33,1%	31,2%
78	33,4%	32,4%
79	35,7%	33,7%
80	37,1%	35,1%
81	38,5%	36,4%
82	40,0%	37,8%
83	41,4%	39,2%
84	42,9%	40,7%
85	44,4%	42,1%
86	45,9%	43,5%
87	47,4%	44,9%
88	48,9%	46,4%
89	50,0%	47,7%
90	50,0%	49,0%



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Reverse Mortgages: the role of the actuaries



Final remarks

- An important factor relating to low reverse mortgage demand is potential borrowers' insufficient knowledge, or product-specific literacy
- Awareness of reverse mortgages is high, but knowledge of contract terms is limited.
- Moreover, the appeal of the product could increase and the sale agreements improves if it would be valued under an actuarial perspective



Final remarks

This study could assist financial institutions and governments in understanding the properties of reverse mortgages from an actuarial point of view, and it provides them with a necessary incentive for developing a reverse mortgage market in collaboration with the actuaries.



Main References

- Alai D. H., Chen H., Cho D., Hanewald K, Sherris M.: *Developing Equity Release Markets: Risk Analysis for Reverse Mortgage and Home Reversion*. North American Actuarial Journal, 18:1, (2014) pp. 217-241.
- Beltrametti L. : *House rich, Cash poor. Come rendere liquida la ricchezza rappresentata dalla casa di abitazione”* Quaderni dell’Osservatorio, Fondazione Cariplo n.26 (2017)
- D’Amato V., Di Lorenzo E., Haberman S., Sibillo M., Tizzano R.: *Pension Schemes versus Real Estate*. Ann Oper Res (2019)
- EIPOA: *EIOPA’s advice on the development of an EU Single Market for personal pension products (PPP)* EIOPA-16/457 04 July 2016
- Fornero E., Rossi M., Virzì Bramati M. C.: *Explaining why, right or wrong, (Italian) households do not like reverse mortgage*. Journal of Pension Economics & Finance, Vol. 15, Issue 2 (2016) pp.180-202.
- L. Yu, C. Jiao, H. Xin, Y. Wang, K. Wang. *Prediction on House Price based on Deep Learning*. International Journal of Computer and Information Engineering Vol:12, No:2, 2018

