IVASS
ISTITUTO PER LA VIGILANZA
SULLE ASSICURAZIONI

Working Paper no. 29

Optimal portfolio allocation: a first view on the role of loans and mortgages among Italian insurers

Agostino Tripodi

February 2024

IVASS
ISTITUTO PER LA VIGILANZA
SULLE ASSICURAZIONI

(decree-law no. 95 of 6 July 2012, converted into law no. 135 of 7 August 2012)

*The "*Working Papers*" series is aimed at enhancing the dissemination of studies and original contributions on insurance issues and stimulate critical comments and suggestions.*

The opinions expressed during the works are attributable to the authors alone and do not bind their respective institutions in any manner.

via del Quirinale 21- 00187
ROMA telephone +39 06 42133.1

The series is available on-line at www.ivass.it

ISSN 2421-4671 (online}

Optimal portfolio allocation: a first view on the role of loans and mortgages among Italian insurers

Agostino Tripodi*†

Abstract

I examine how the interaction between the Solvency II regime and nation-based regulations impact insurers' asset allocation. I document that Italian insurers invest a lower share of assets in mortgages and loans than other EU countries, e.g. the Netherlands, consistently with the Italian regulation that sets strict requirements on insurers' investments in mortgages and loans. A simulation analysis based on a variant of Markowitz Portfolio theory shows that current portfolio allocation is suboptimal relative to a situation in which more investments in mortgages and loans are allowed. The different results between 2021 and 2022 also suggest that missed opportunities vary with interest rates. These results can contribute to the ongoing debate on the revision of Solvency II. The analysis abstracts from liquidity risk and systemic risk, minimized by current Italian regulation, and from other economic aspects to be considered in order to perform cost-benefit analysis.

JEL classification: G11, G22, G23

Keywords: Loans, Insurance companies, Solvency II regulation, Portfolio optimization.

*IVASS, Research and Data Management Directorate, Research and Statistics Division.

†The opinions and errors in this paper are solely by the author and do not reflect the views of IVASS.

Contents

Acknowledgments: The author would like to thank Marco Cosconati, Andrea Fabiani, Pietro Franchini, Giovanni Guzzarotti, Christian Kubitza, Roberto Novelli, Stefano Pasqualini, Enzo Ricci, Sergio Sabbatucci and Federico Maria Signoretti for helpful comments and suggestions on this paper.

1 Introduction

Insurers manage significant assets in capital markets (759 billion euros in Italy and 7.182 billion euros in the EU in 2022). A prominent characteristic of the insurance industry is that insurers cash premiums in advance and cover claims payout within a maturity period that depends on the various lines of business. For example, an insurance life policy has a maturity of twenty or thirty years, while motor insurance and similar non-life contracts usually consider a one-year horizon. Let us consider the example of a pure endowment policy, where a single premium is cashed in, and a lump sum will be paid at maturity if the policyholder is still alive. Given a maturity of twenty years for an insured sum of 10,000 euros, an expected yearly rate of 1% and a survival probability of 97%, the corresponding premium will be roughly 7,950 euros.[1] Considering a portfolio of 100 policyholders, the total premiums earned amount to 795,000 euros and, leaving aside the demographic risk, the insurer will pay 970,000 euros at maturity. The capital gain that allows to break even is 175,000 euros (i.e. a yearly rate of return of 1%), and any return exceeding 1% will result in a profit for the insurer. These calculations suggest that asset management has a first-order effect on profitability.

A recent and promising area of research is how insurers allocate their assets in response to regulation. For example, Fringuellotti and Santos (2021) document an increase in collateralised loan obligations (CLOs) due to the NAIC capital requirements stemming from how assets are rated in terms of risk. Studies on the effect of the Solvency 2 (S2) regime on European insurers' investment decisions are limited. In this paper I try to fill this gap, and I focus on how the S2 capital requirements interact with national regulation in determining Italian insurers' asset allocation. Specifically, Italian insurers' portfolios are characterised by a large portion of bonds (60% of the total assets held by Italian insurers) and a much lower quota in equity, derivatives and real estate assets. The Italian regulation stipulates that investments in mortgages and loans (LM), either to individuals/firms or through collateralised securities, cannot exceed 5% of their assets. Italian insurers hold a negligible amount of LM, compared to Dutch insurers holding 24.1% in LM in Q4-2022. On the other hand, although the S2 risk capital charge for retail loans can be assimilated to corporate bonds with ratings between BBB and BB, their (exptected) return is typically higher. Analogously, as for government bonds, under S2 there is no risk capital charge on residential loans if their loan to value ratio (LtV) is less than than 80%.[2] In sum, investments in LM are charcterized by higher (economic) risk and (expected) returns than alternative assets requiring the same S2 regulatory capital.

[1] $U = C_n p_x (1+i)^{-n}$, where C is the insured sum, ${}_n p_x$ is survivor probability for n years at age x and i is an interest rate.

[2] For residential loan with LtV greater than 80%, the risk capital charge increases linearly with a maximum of 3% for a LtV equal to 100% .

Given the incentives stemming from the S2 regime, a natural question to ask is whether/how much the nation–wide regulation narrows Italian insurers' financial investments opportunities. Specifically, I address two main questions: (i) could Italian insurers improve their asset allocations if the nation-wide constraint on LM were to be altered? (ii) does the more recent variation of interest rates affect the degree of inefficiency (if any) implied by such a constraint?

I propose a measure for the 'financial' shadow cost of the cap for LM Italian insurers.[3] The simulations are based on an optimal Markowitz portfolio allocation framework under two constraints: (i) the S2 capital requirements and (ii) caps on LM. By varying the constraint (ii), the risk-return trade-off measures the financial shadow cost of different caps on LM. I assume that insurers hold a portfolio of government and corporate bonds, retail and residential loans; market and counterparty risks are calculated adopting S2 risk charge as a risk metric. In the simulation exercise different portfolio allocations are rated on the basis of their expected return and capital requirement, thus allowing current and hypothetical asset configurations to rank under counterfactual caps on LM. Although the exercise I perform is primarily meant to contribute to evaluate how the interaction of S2 and nation–based regulation shapes asset allocations, I also discuss whether the S2 regime measures realistic economic risk implied by LM.

Two results emerge. First, Italian insurers could obtain more efficient portfolios with higher returns and lower capital requirements by increasing LM through direct lending or collateralised loans. Second, the missed opportunities stemming from the current cap on LM vary as a function of interest rate. In 2021, 70.6% of simulated portfolios, including a larger quota of LM, were more efficient than the base portfolio, dropping to 28.9% in 2022, due to higher interest rates in the bond market.

While these results suggest that the financial shadow cost of a cap on LM is significant, several caveats of the analysis are discussed in section 3.

Related literature: Fringuellotti and Santos (2021) show that U.S. insurers have increased their investment and that the growth in CLO's investments has far outpaced that of bonds.

[3]Such a measure does not include internal and external costs of granting credit and does not consider the creditworthiness of borrowers.

They document that this behaviour reflects a search for yield but also that the driver for this preference is related to the insurance capital regulation. They show that U.S. insurers have increased their investment in collateralised loan obligations (CLO') and that the growth in CLO' investments has far outpaced bonds. Typically, models for optimal asset allocation are based on Markowitz's Portfolio Selection Theory (Markowitz (1952)), analysing the trade-off between risk and return. Schlütter et al. (2022) examine market risk components, namely interest rate and credit risk, measure risks using the Solvency ratio, and focus on the allocation of socially responsible investments. They assume that there is no pre-existing portfolio, following, among others, Ballestero et al. (2012), Bilbao-Terol et al. (2012), Bilbao-Terol et al. (2013), Cabello et al. (2014), Calvo et al. (2016), Liagkouras et al. (2020) and Vo et al. (2019). Braun et al. (2017) optimise a life insurance asset allocation in the context of classical portfolio theory where the firm is subject to the Solvency II market risk capital requirements. For six asset classes (Stocks, Government bonds, Corporate bonds, Real estate, Hedge funds, Money market), they apply the well-known quadratic optimization function (see, e.g. Kroll et al., 1984) to minimize the variance given an expected return; the optimisation problem includes investment limits. Fischer and Schlütter (2015) explore an insurer's optimal capital and investment strategy when capital requirements are based on a standard formula. They demonstrate that the calibration of the standard formula strongly influences the insurers capital and investment strategy. They consider an insurance company in a one-period setting and conclude that the default probability does not necessarily decrease when reducing the investment risk. Dčhert et al. (2022) develop a multi-criteria approach with four objective functions for strategic asset allocation, where the solvency ratio under the Solvency II directive is considered among these functions. Koijen and Yogo (2019) go beyond the traditional asset pricing model based on solid assumptions about the asset demand of institutional investors. They develop an alternative asset pricing model with flexible heterogeneity in asset demand that matches institutional and household holdings. They also investigate how different regulatory requirements for banks and insurance companies would affect asset prices and investments. In a previous paper, Koijen and Yogo (2015) demonstrate how the pricing behaviour of financial institutions is significantly affected by financial frictions. They estimate the shadow cost of capital that depends on the statutory reserve in the U.S. and is different among insurance companies because they hold heterogeneous portfolios.

This paper is organised as follows: the next section contains an overview of the data and descriptive evidence. Section 2 focuses on the Italian market, with an overview of the regulatory framework. Section 3 explains the risk measurement under Solvency II regulation and the approach adopted in this article; section 4 described the data used in the analysis and some descriptive statistics. Section 5 describes the relevant features of the S2 regimes; section 6and 7 contains the simulation exercise and results. Section 8 contains concluding remarks.

2 Institutional background

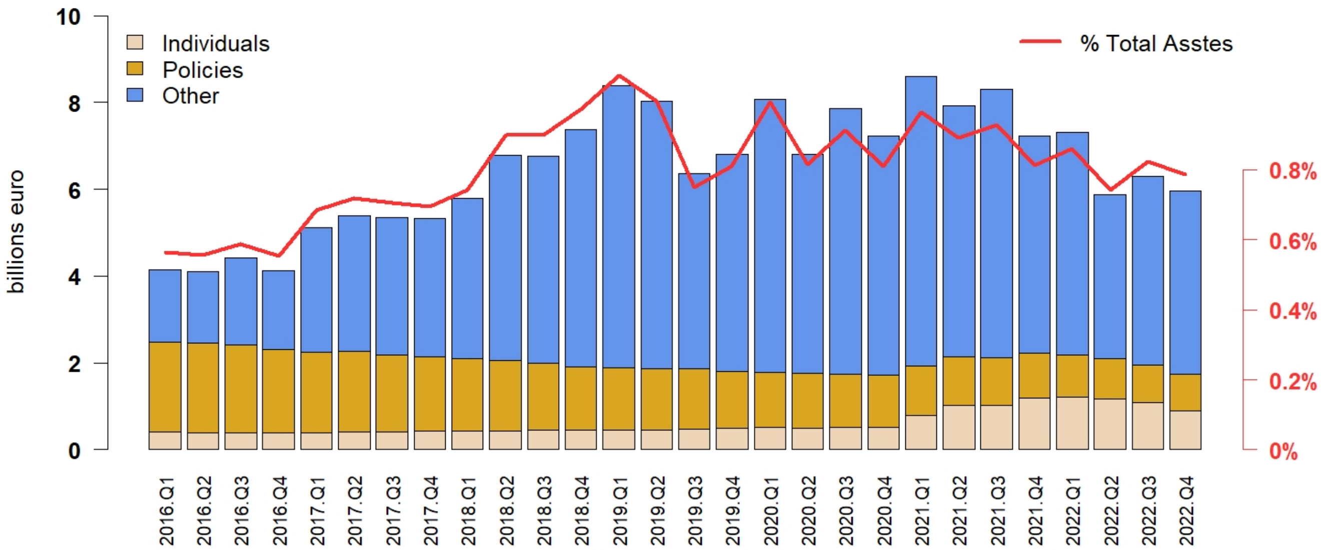
The LM settled by Italian insurers are subject to Art. 38-2 of Code of Private Insurance - Legislative Decree n. 209/2005 and IVASS Regulation No. 24/2016. According with the normative, Italian insurers can use mortgages and loans to cover the insurance liabilities. However they are subject several constraint: (i) borrowers cannot be individuals or small firms; (ii) insurers are required to draw up a plan subject to approval by IVASS and it establish conditions and limits; (iii) LM are capped at 5% on total assets[4] for loans without a warranty, that we refer it in next as retail loans. However, insurers can invest in LM via securitization (or cash pools) by purchasing LM on the secondary market. Figure 1 illustrates the times series of the amount and incidence of LM for Italian insurers. It shows a negligible upward trend, from 0.56% in Q1-2016 to 0.79% in Q4-2022. As to the composition by type (Individual/Policies/Other), we observe a slow increase in the individual share on total loans, from 7.25% in Q4-2020 to 16.62% in Q4-2022.

3 Limitations of the analysis

It is important to stress several limitations of the analysis. First, current limitations on LM by the Italian regulation shield Italian insurers from several risks that S2 regulation does not keep into account, among which: liquidity risk and systemic risk. As an example, unexpected payouts driven by an increase of surrender rates can most likely be dealt by selling bonds rather loans that are less liquid assets. Current regulation might also be useful to contain systemic risk generated by borrowers' credit risk arising in financial crisis or after macroeconomic shocks (e.g. loss of employment) and to contain contagion between the insurance and banking sectors. Also, for loans without a warranty, the credit risk has a risk capital charge that is an intermediate level between corporate bond with rating BB and BBB, this measure is not suitable for all

[4]Excluding assets related to index or unit-linked policies.

Figure 1: Loans and mortgages held by Italian insurers, Q1-2016 - Q4-2022



Note: Time series on a quarterly basis of loans and mortgages granted by Italian insurers. The bars show (left side) the value in billion euros, while the red line (right side) measures the incidence on total assets value.

borrowers, because it does not keep into account the specific risk profile. Moreover, (i) allowing insurers to grant credit does not necessarily imply that insurance company would be able to evaluate creditworthiness, an activity that requires experience and specific knowledge and (ii) the analysis does not include fixed and hidden costs related to hiring competent staff and processes to assess the creditworthiness of borrowers or to manage borrowers' default or insolvency. Considering that the amount of LM in the Italian market has always been much below the constraint set by Italian law, fixed costs are likely to have discouraged Italian insurers from investing a higher share of their assets in LM. Finally, the simulations in this paper adopted the current Standard Formula in Solvency II as the risk metric, with all its limitations and assumptions, compared to more appropriate measures of economic risk that one would adopt to perform cost–benefit analysis to evaluate the desirability of altering the cap on LM.

4 Data and descriptive evidence

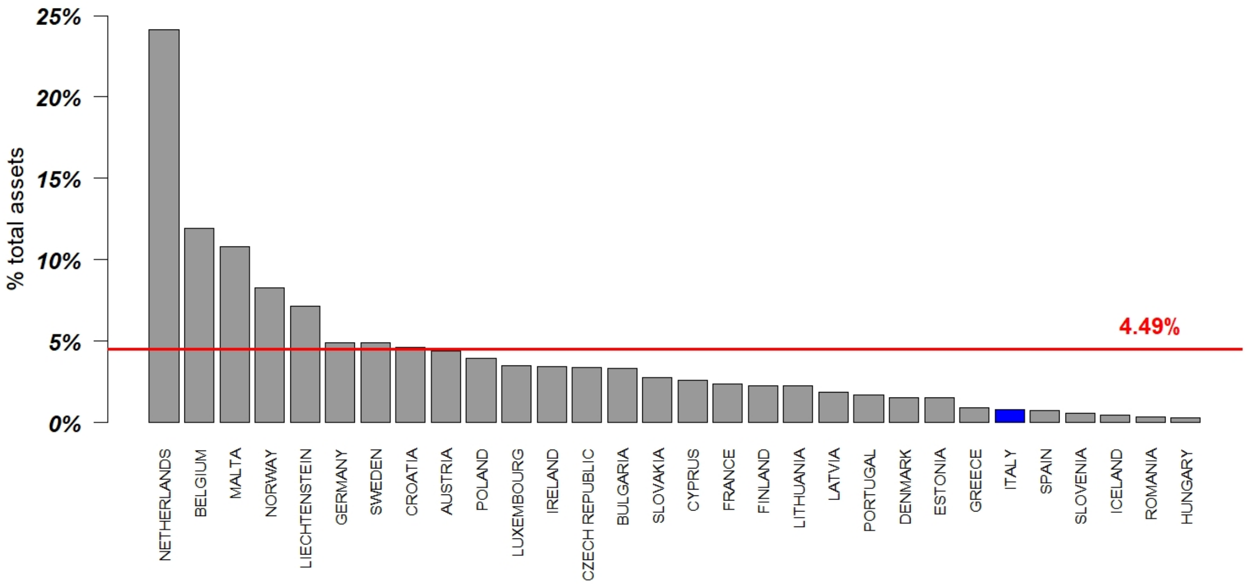
The data source is the Quantitative Reporting Template (QRT) required by Solvency II. Loans and mortgages fall into the following three categories:

- *Loans on policies* - Loans made to policyholders, collateralised on policies (underlying technical provisions);
- *Loans and mortgages to individuals* - Financial assets created when creditors lend funds to individuals, with or without collaterals, including cash pools;
- *Other loans and mortgages* - Financial assets created when creditors lend funds to debtors, not classifiable in the previous items, with or without collaterals, including cash pools.

The figure 2 illustrates the incidence of LM compared to total assets, excluding assets held to cover index or unit-linked policies. It turns the spotlight on the heterogeneity across European insurers. Dutch insurers hold 24.12%, in Belgium the share is 11.91%, while Italian insurers only allocate 0.79% of their assets in LM (for details see table 8). As shown in Table 1, there exist marked differences across countries in term of LM composition. In some countries, the share of loans to private consumers compared to total LM is low; in France it stands at 2.54%, in Italy at 15.19%. In other cases the incidence is high, for example in Germany and the Netherlands it accounts for 53.92% and 65.26% of total LM, respectively.

Assets fall into seven categories: government bonds, corporate bonds, other investments including property, holdings in related undertakings and equities, collective investments undertakings, derivatives, deposits other than cash equivalents, cash and cash equivalents (notes and coins in circulation and deposits exchangeable for currency on demand at par), reinsurance recoverables (amounts recoverable from reinsurance contracts and special purpose vehicles), loans and mortgages (financial assets instrumental in lending funds, either with or without collateral, including cash pools), other assets including those not elsewhere shown. Table 1 shows the portfolio allocation for some countries and the average for European insurers. Italian insurers invest mainly in government and corporate bonds, accounting for 59.64% of total assets, while LM represent 0.79%. In the Netherlands, investment in bonds account for 31.23% and LM for 24.12%. The differential weight of LM between the Netherlands and Italy equals 23%, offset by a difference of -28% for bonds. In the following sections, a simulation measures whether, with-

Figure 2: Country-specific Incidence of loans & mortgages.



Note: The red line is the weighted EU average.

out the legal constraints described in Section 3, the Italian undertakings' investments would benefit from granting more credits, substituting the current bond investments.

	NETHERLANDS	BELGIUM	GERMANY	FRANCE	ITALY	EU
Government Bonds	**17.99**	33.79	14.01	23.41	**42.64**	21.89
Corporate Bonds	**13.24**	17.93	16.58	23.94	**17.00**	19.52
Other Investments	32.91	21.19	53.71	39.39	29.58	41.06
Reinsurance recoverables	0.58	7.69	3.76	4.29	1.30	4.94
Cash Equivalent	1.96	2.24	0.54	0.81	1.43	1.39
Any Other Asset	9.20	5.25	6.51	5.82	7.26	6.71
Loans and mortgages	**24.12**	11.91	4.88	2.35	**0.79**	4.49

Table 1: Asset Allocation at Q4-2022 - EU comparison

5 Solvency Capital Requirement

European insurers calculate a Solvency Capital Requirement (SCR) based on a 99.5% value-at-risk measure over one year, so the SCR is related to a ruin probability of 0.5%.[5] For our purposes, we consider the Standard Formula to calculate the SCR, following a common rule defined by European regulation.[6] In the current version of the Standard Formula, LM are subject to the Market Risk and Counterparty Risk assessment. Fixed income assets, such as bonds and loans, contribute to the SCR through interest and spread risk in the Market Risk module. LM contribute to counterparty risk only when not included in the spread risk sub-module. While SCR is the regulatory risk charge, other measures of real economic risk can be different. Also, additional charges are expected under Solvency II, even if not included in quantitative requirements to cover specific risks, based on qualitative requirements such as the prudent person principle, risk management system, own risk and solvency assessment. Table 3 summarizes the main differences between bonds and loans from a capital requirement perspective. Generally, bond borrowers are central governments or large firms with a public rating, while loans' borrowers are individuals. Borrowers of loans have private information about their creditworthiness that is not observable by lenders, so there is a high level of asymmetric information. Loans have a higher liquidity risk than bonds because the bonds can be settled on short notice in a secondary market, while for loans, the lender cannot ask for a sudden refund.

In the next sections the SCR per euro of asset is denoted with:

$$\rho(\omega) = \sqrt{\psi(\omega)^2 + \phi(\omega)^2 + \eta(\omega)^2 + 0.5 * \eta(\omega)\sqrt{\psi(\omega)^2 + \phi(\omega)^2}} \tag{1}$$

where $\omega = [\omega_1, \omega_2, \ldots, \omega_m]$ is the vector of the allocated shares to the m asset class. For more details see the appendix A.

6 Simulation exercise

This simulation exercise aims to check whether investing assets in bonds and loans results in a higher return on assets and a lower risk (SCR per euro) compared to a base portfolio with only

[5] Directive 2009/138.

[6] Commission Delegated Regulation (EU) 2015/35.

bonds. We consider the case where an insurer can choose among four asset classes: Government bonds, Corporate bonds, retail loans and residential loans. The vector of shares for each asset class is $\omega = \{\omega_1, \omega_2, \omega_3, \omega_4\}$. For government bonds, we use the indexes of annual return available from an external information provider (Refinitiv Datastream), organised by maturity bucket and issuer country. The data set covers around 94% of the Italian insurance portfolio. For corporate bonds, we use iBoxx indexes by maturity bucket and rating. Finally, from the statistics on loans at Q4-2021 and Q4-2022 published by the Bank of Italy, we use an annual return of 7.64% in 2021 and 9.22% in 2022, while the return from residential loans equals 1.74% in 2021 and 3.36% in 2022.[7] The loan maturity is assumed to be five years for retail loans and 20 years for residential loans.[8]

Table 2 summarizes the average values for rate of return and for risk coefficients ψ, ϕ and η. The risk parameters for bonds ($i = 1, 2$) are calculated using the list of assets from the Solvency II templates (S.06.01 and S.06.02); for loans, the interest rate risk parameter ψ_i is obtained by multiplying the duration by shock up, the spread risk parameter is obtained using the equation (6) for unrated bonds (CQS=7), finally the default risk parameter (only for residential loans) is calculated by the equation (7) and we assume $LtV \leq 0.8$ that it is the maximum amount that banks usually lend for residential mortgages, so $\eta_i = 0$.

Assets class	i	r_i	ψ_i	ϕ_i	η_i
Government	1	0.0390	0.0757	0.0000	0.0000
Corporate	2	0.0570	0.0481	0.0939	0.0000
Retail	3	0.0922	0.0350	0.1050	0.0000
Residential	4	0.0336	0.1000	0.0000	0.0000

Table 2: Rate of return and risk parameters in Q4-2022.

The base portfolio is defined under the assumption that each insurer has the same allocation in bonds as the Italian average in Q4-2022, reported in Table 10 for government bonds and Table 14 for corporate bonds. The mix between government and corporate bonds reflects the average composition of the Italian insures' portfolio, resulting in $\omega_1 = 0.7$ and $\omega_2 = 0.3$. In the simulation, a share α is allocated to loans with a different composition $\beta \in (0, 1)$ between

[7] https://www.bancaditalia.it/statistiche/index.html?com.dotmarketing.htmlpage.language=1

[8] The duration for retail and residential loans is 2.9 and 9.6 years in 2022, and 3.0 and 10.3 in 2021.

retail and residential, so the portfolio shares are $\omega_1 = 0.7(1-\alpha)$, $\omega_2 = 0.3(1-\alpha)$, $\omega_3 = \beta\alpha$ and $\omega_4 = (1-\beta)\alpha$.

Figure 3 summarizes the simulation results showing the trade-off between risk and return in 2021 and 2022. The risk is reported on the x-axis, measured by the regulatory risk capital charge for euro of assets, while the return is on the y-axis. The main result is that investing in LM makes it possible to obtain portfolios with a greater return and lower risk than the base portfolio (see the grey area). The result holds for both 2021 and 2022, but in 2022 the return of the portfolio with LM is lower due to the reduction in the spread between bonds and loan returns. Moreover, under the same assumptions, in 2021 no portfolio with LM has a lower return than the base portfolio, while in 2022 some LM portfolios have a lower return than the base portfolio. Since 2022 the rate of residential loans was lower both for government and corporate bonds, the advantage is for retail loans.

7 Shadow cost of regulation

To investigate if the regulation about LM is binding, we examine a constrained optimisation problem maximising the portfolio return $r(\omega)$ subject to a risk tolerance $\bar{\rho}$ and a duration constraint. The metric for risk tolerance adopts the Standard Formula for SCR as described above. We introduce a lower bound d_{lw} and an upper bound d_{up} on duration because the insurers usually set a duration level for assets aligned with the duration of liabilities. The maximum level for LM is $\bar{l}$. The insurer's maximization problem is to choose $\omega = \{\omega_1, \omega_2, \omega_3, \omega_4\}$ containing the fraction of each type of asset:

$$
\begin{aligned}
\max_{\omega} \quad & r(\omega) = \sum_{i=1}^{m} \omega_i r_i \\
\text{s.t.} \quad & \rho(\omega)^2 = \psi(\omega)^2 + \phi(\omega)^2 \leq \bar{\rho}^2 \\
& d(\omega) = \sum_{i=1}^{m} \omega_i d_i \geq d_{lw} \\
& d(\omega) = \sum_{i=1}^{m} \omega_i d_i \leq d_{up} \\
& \alpha = \omega_{m-1} + \omega_m \leq \bar{l} \\
& \sum_{i=1}^{m} \omega_i = 1 \\
& \omega_i \geq 0 \quad i = 1, \ldots, m
\end{aligned} \tag{2}
$$

The Lagrangian for problem 2 is :

$$
\begin{aligned}
L(\omega, \lambda) &= r(\omega) - \lambda_1 \left(\rho(\omega)^2 - \bar{\rho}^2\right) + \lambda_2 \left(d(\omega) - d_{lw}\right) - \lambda_3 \left(d(\omega) - d_{up}\right) + \\
&- \lambda_4 \left(\alpha - \bar{l}\right) - \lambda_5 \left(\sum_{i=1}^{m} \omega_i - 1\right) + \sum_{i=1}^{m} \lambda_{5+j} \omega_i
\end{aligned} \tag{3}
$$

Let (ω^*, λ^*) be the vector of optimal solution, the Lagrange multiplier λ_4^* measures the sensitivity of the optimal value $r(\omega^*)$ to changes in the legal constraints $\bar{l}$. λ_4^* is *shadow cost* of loan constraints and measures the extra-return of portfolio that an insurer could have realised with no constraint on loans. Let $\omega^*(\bar{l})$ be the optimal solution for a fixed level of loans constraint $\bar{l}$ (given the same value of $\bar{\rho}, d_{lw}, d_{up}$), the results is $\frac{dr(\omega^*(\bar{l}))}{d\bar{l}} = \lambda_4^*$.

Data input for problem (2) are Italian bond indexes for government bonds, iBoxx indexes BBB for corporate bonds (see Table 9) and for LM the same data as in section 6. We analyse the problem from Q4-2016 to Q4-2022 at a quarterly frequency.

The time series in Figure 4 shows the results of problem 2 with an LM constraint of $\bar{l} = 5\%$, a risk tolerance of $\bar{\rho} = 9\%$ and an interval for the duration (7.75,8.25) years. The plot shows a strong correlation between shadow cost and government and corporate spread with retail loans, respectively 81% and 92%; on average an increase of 1% of the government spread generates an increase of 0.013% in shadow cost. The average shadow cost for the variation $\Delta\bar{l} = 1\%$ is

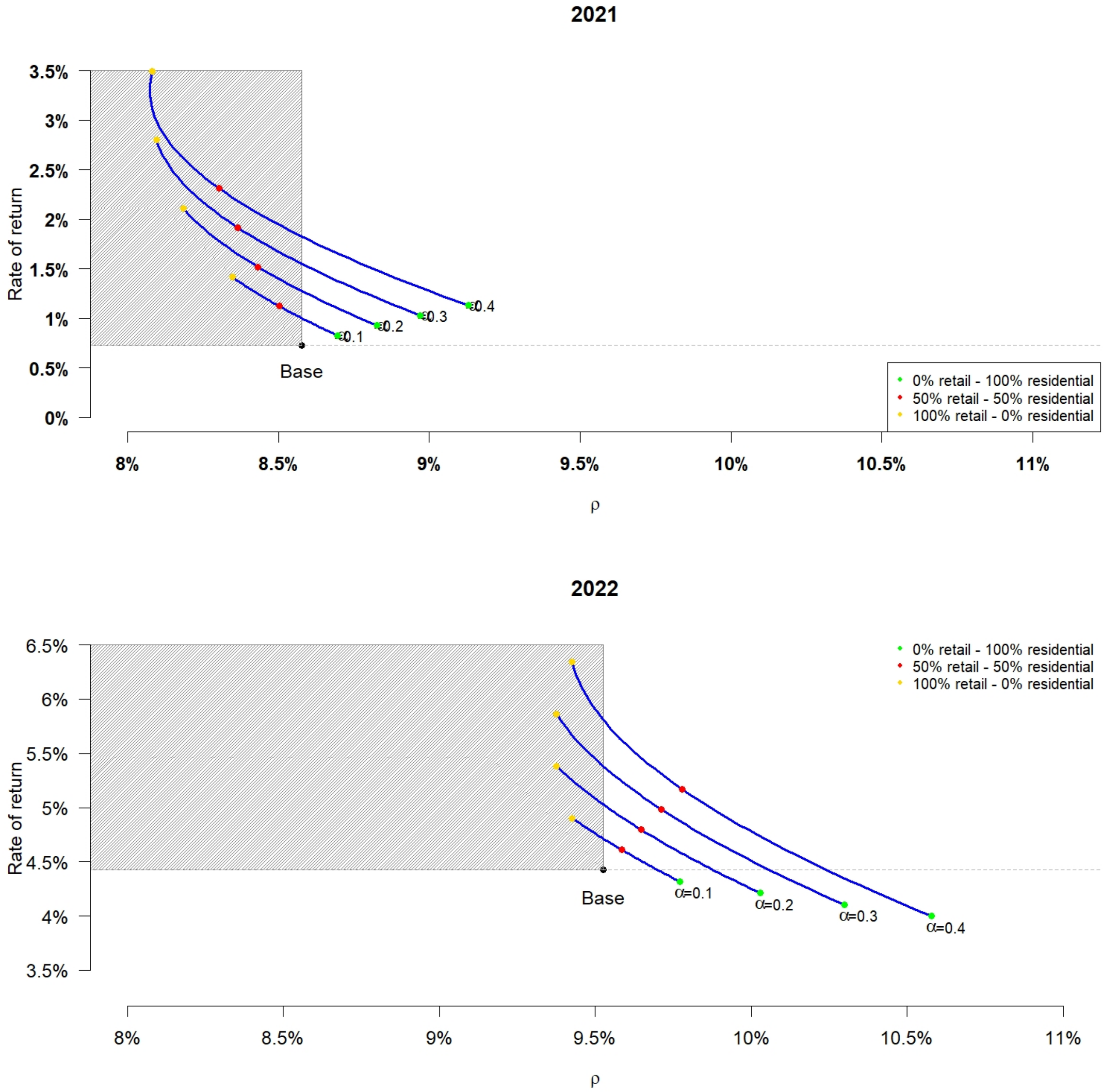
0.066% over 2016-2022. Since the shadow cost is a local solution, the behaviour of shadow cost is analysed by varying $\bar{l}$ into $(0, 1)$.

The results are summarised in Figure 5, which shows that the shadow cost has a discontinuous path with several jumps that depend on risk tolerance. The jump in the shadow cost implies a kink of the optimal return (red line) since, for a fixed tolerance level, there is a critical value of loan constraints above which the increase in optimal return is smaller with the shadow cost discontinuously falling. This phenomenon happens because retail loans contribute to reaching the maximum risk tolerance while having a much higher return than the other categories of assets. Figure 6 reports the optimal asset allocation when loan constraint $\bar{l}$ varies between $(0, 1)$. Comparing Figures 4 and 6, the optimal share produces the same kinks of shadow costs.

8 Conclusion

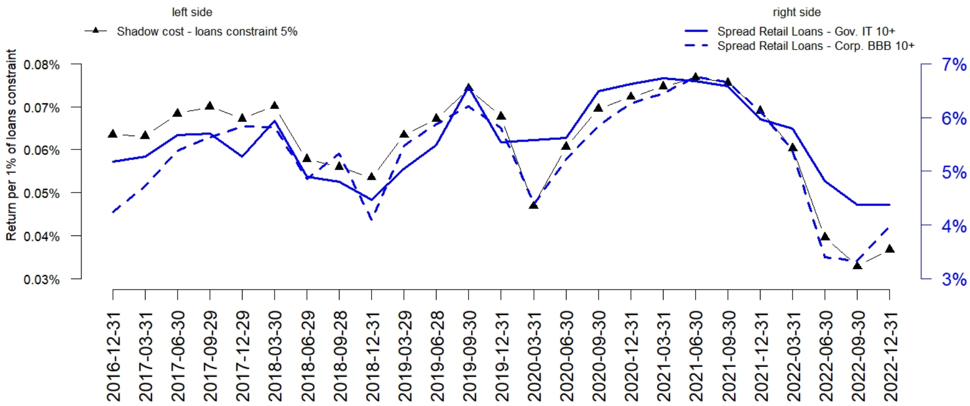
In this paper the optimality of investment portfolios held by Italian insurers is analyzed. The constrained optimization exercise indicates that the shadow cost of constraints on LM is primarily related to the spread between loans and bonds but depends on other parameters, including risk tolerance. The effect of an optimal allocation in terms of risk-return removing the regulatory constraints on investments in LM is less prominent in periods with higher rates (i.e. in 2022; see Figure 3) than in previous years. The corresponding shadow cost of regulation is also strongly affected by the spread between bonds and loans, which is lower in 2022. Notwithstanding its previously described limitations, current analysis can help to assess the benefits in terms of portfolios efficiency that could be obtained by allowing Italian insurers to invest more in collateralized loan/debt obligations (CLO/CDO). More research is needed to evaluate the costs in terms of increased systemic and idiosyncratic risks to perform a fully edged cost benefit analysis. Several limitations of the analysis are discussed as well as pathways of future research on the topic.

Figure 3: Simulation exercise



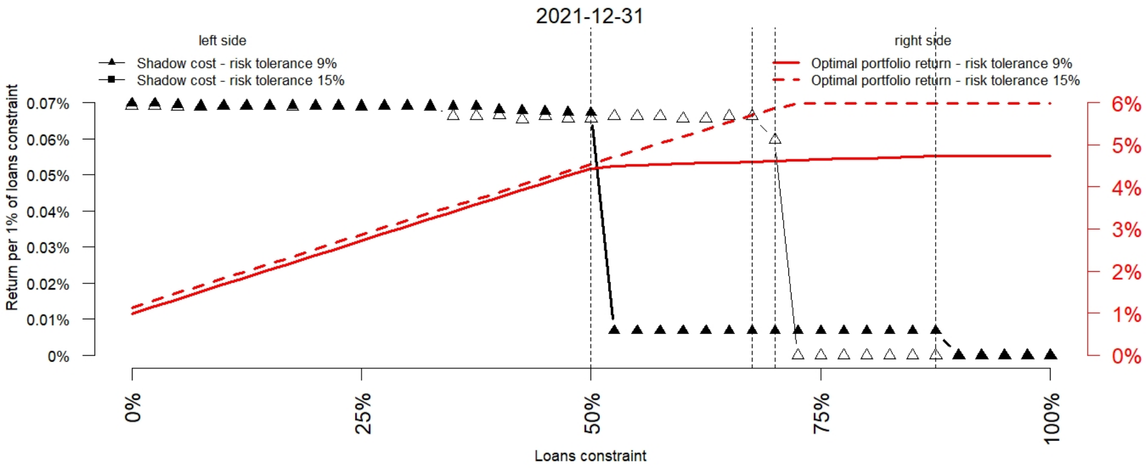
Note: x-axis SCR per euro of assets and y-axis rate-of-return. The four curve show different levels α (10%, 20%, 30%, 40%) of assets that are allocated to loans. For the same curve the mix $\beta \in (0, 1)$ between retail and residential loan is different.

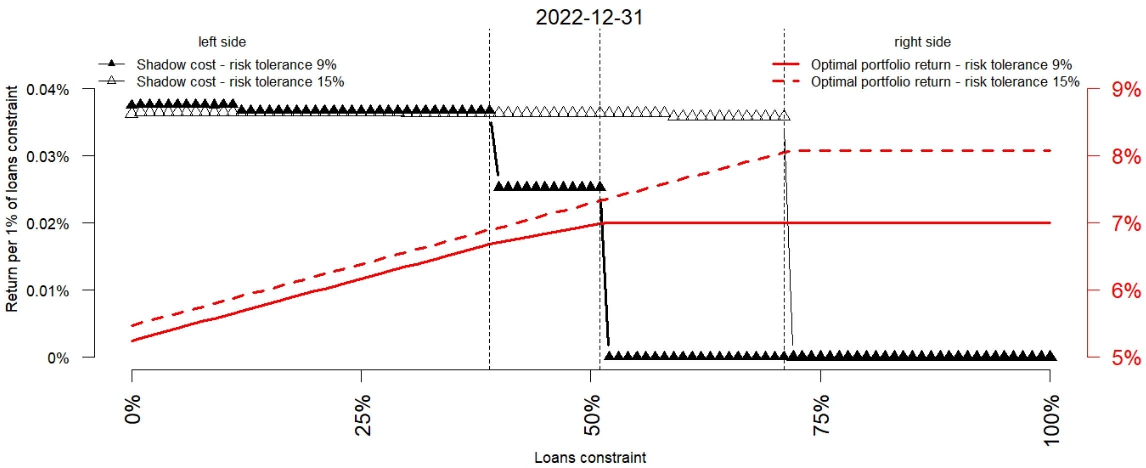
Figure 4: Shadow cost of law constraint, for different date.



Note: Left y-axis measures the shadow cost as reduction of optimal return for a variation of 1% in the loans constraint, for constraint $\bar{\rho} = 9\%$, $d_{lw} = 7.75$ years and $\bar{l} = 5\%$. Right y-axis reports the spread between annual return of retail loans and IT Government bonds and corporate BBB, both with a maturity of 10+ years. On the x-axis there is the reference date.

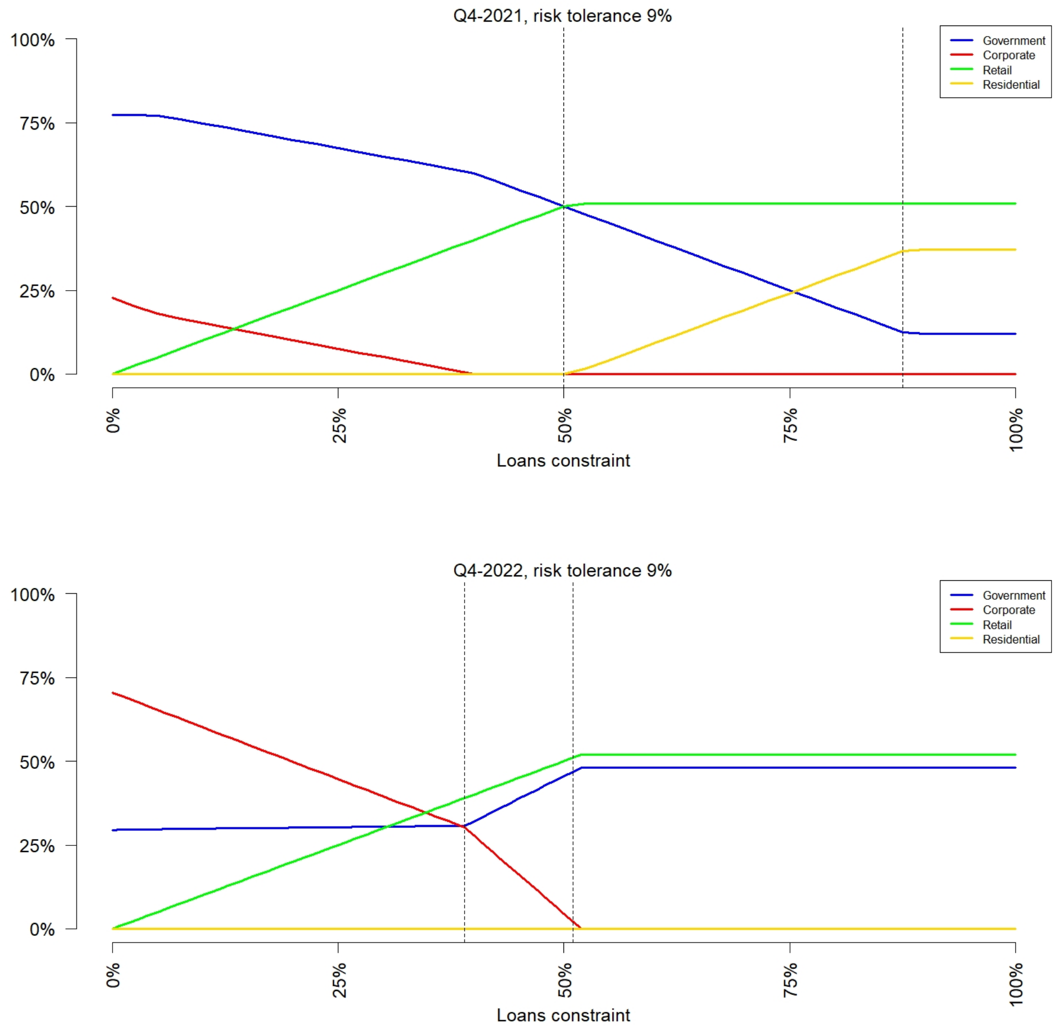
Figure 5: Shadow cost for different levels of law constraint.





Note: The left y-axis shows the shadow cost measured as reduction of optimal return for a variation of 1% for different level $\bar{l}$ of loans constraint, the results are obtained for constraint $\bar{\rho} = 9\%$ and $\bar{\rho} = 15\%$, $d_{lw} = 7.75$ years, $d_{up} = 8.25$ years. The right y-axis reports the optimal return and x-axis shows the different level $\bar{l}$.

Figure 6: Optimal allocation for different levels of law contraint.



Note: This figure illustrates optimal allocation distinct for assets class in y-axis, the results are obtained for constraint $\bar{\rho} = 9\%$, $d_{lw} = 7.75$ years, $d_{up} = 8.25$ years. The x-axis shows the different level $\bar{l}$.

References

Ballestero, E., Bravo, M., Perez-Gladish, B., Arenas-Parra, M. and Pla-Santamaria, D. 2012. Socially responsible investment: A multicriteria approach to portfolio selection combining ethical and financial objectives. *European Journal of Operational Research* 216(2), 487-494.

Bilbao-Terol, A., Arenas-Parra, M. and Canal-Fernandez, V. 2017. Selection of sociallyresponsible portfolios using goal programming and fuzzy technology. *Information Sciences* 216(2), 189, 110-125.

Bilbao-Terol, A., Arenas-Parra, M., Canal-Fernandez, V. and Bilbao-Terol, C. 2013. Selection of socially responsible portfolios using hedonic prices. *Journal of business ethics* 115(3), 515-529.

Bragt D., Steehouwe H. and Waalwijk F. 2010. Market Consistent ALM for Life InsurersSteps toward Solvency II. *The Geneva Papers* 2010, 35, (92-109).

Braun A., Schmeiser H. and Schmeiser F. 2017. Portfolio Optimization Under Solvency II: Implicit Constraints Imposed by the Market Risk Standard Formula. *The Journal of Risk and Insurance* Vol. 84, No. 1, 177-207 (2017).

Cabello, J. M., Ruiz, F., Pérez-Gladish, B. and Méndez-Rodríguez, P. 2014. Synthetic indicators of mutual funds environmental responsibility: An application of the reference point method. *European Journal of Operational Research* 236(1), 313-325.

Schlütter S., Fianu E.S., and Gründl H. 2017. Fuzzy portfolio selection with non-financial goals: exploring the efficient frontier. *Annals of Operations Research* 245(1), 346.

Dčhert K., Grindel R., Leoff E., Mahnkopp J., Schirra1 F. and Wenzel1 J. 2022. Multicriteria asset allocation in practice. *OR Spectrum* 44, 349-373 (2022).

Fischer K. and Schlütter S. 2015. Optimal Investment Strategies for Insurance Companies when Capital Requirements are Imposed by a Standard Formula. *The Geneva Risk and Insurance Review* 2015, 40, (15-40).

Fringuellotti F. and Santos J.A.C. 2021. Insurance Companies and the Growth of Corporate Loans' Securitization. *Federal Reserve Bank of New York* Staff Reports no. 975.

Koijen R. and Yogo M. 2015. The Cost of Financial Frictions for Life Insurers. *American Economic Review* 2015, 105(1): 445-475.

Koijen R. and Yogo M. 2019. A Demand System Approach to Asset Pricing. *Journal of Political Economy* 2019, vol. 127, no. 4.

Kroll, Y., H. Levy, and H. M. Markowitz, 1984. Mean-Variance Versus Direct Utility Maximization. *Journal of Finance* 1984, 39(1): 47-61.

Kubitza K. 2021. Investor-Driven Corporate Finance: Evidence from Insurance Markets . Available at SSRN: https://ssrn.com/abstract=3957964.

Liagkouras, K., Metaxiotis, K. and Tsihrintzis, G. 2020. Incorporating environmental and social considerations into the portfolio optimization proce
ss. *Annals of Operations Research* pp. 1-26.

Markowitz, H. M. 1952. Portfolio selection. *Journal of Finance* 7(1), 77-91.

Schlütter S., Fianu E.S., and Gründl H. 2017. Responsible investments in life insurers optimal portfolios under solvency constraints. *ICIR Goethe University Frankfurt* Working Paper Series No. 45/2022.

Vo, N. N., He, X., Liu, S. and Xu, G. 2019. Deep learning for decision making and the optimization of socially responsible investments and portfolio. *Decision SupportSystems* 124, 113097.

	Bonds	Loans
Borrower	Large + Rated	Small + Unrated
Information asymmetries	Low	High
Liquidity	Medium-Low	Low-Very Low

Table 3: Bonds vs Loans

A Details on SCR calculation

Market risk module: the market risk module consists of sub-modules related to interest rate risk, equity risk, property risk, spread risk, currency risk and market risk concentration. Fixed income assets are considered only in the interest rate risk and spread risk modules.

Let $i(t,s)$ for $t > s$ be the term structure of annual interest rate, where the *interest rate risk* is the possibility that a loss may arise from a change in interest rates. Let $X = \{X_1, X_2, \ldots, X_n\}$ and $Y = \{Y_1, Y_2, \ldots, Y_n\}$ be respectively the cash in for fixed income assets and the cash out for liabilities, both payable on years $k = 1, 2, \ldots, n$, then the present value at time t of assets is $V(t) = \sum_{k=1}^{n} X_{t+k} \left(1 + i(t, t+k)\right)^{-k}$ and, similarly, the present value of liabilities is $L(t) = \sum_{k=1}^{n} X_{t+k} \left(1 + i(t, t+k)\right)^{-k}$. Thus the net asset value is $N(t) = V(t) - L(t)$ and the *interest rate risk* is the possibility that a loss may arise from a change in interest rates. Let $\delta^{\pm}(t,s)$ be the instantaneous variation (so called shock) of $i(t,s)$, where $'+'$ denotes a *shock up* and $'-'$ a *shock down*, the variation of the net asset value is $N^{\pm}(t) = \sum_{k=1}^{n} \left(X_{t+k} - Y_{t+k}\right) \left(1 + i(t, t+k) \pm \delta^{\pm}(t,s)\right)^{-k}$, then the SCR for interest rate risk is:

$$SCR_{int} = \max\left[N(t) - N^{+}(t), N(t) - N^{-}(t)\right]. \tag{4}$$

For our purpose, we consider only the shocks applied to cash-in X, because our objective is to measure the change in asset value due to a variation in interest rate, so we are considering the shock up. Let i be the index related to i^{th} assets held in the portfolio, we denote with $\psi_i = 1 - \frac{V_i^{+}(t)}{V_i(t)}$ the SCR_{int} per euro of i^{th} asset value:

$$SCR_{int,i} = V_i(t)\psi_i \tag{5}$$

and the overall SCR for interest risk, for m assets, is obtained by the sum $SCR_{int} = \sum_{i=1}^{m} V_i(t)\psi_i$.

The *spread risk* covers the losses in the asset value due to changes in the level of credit spread over the risk-free interest rate term structure. The spread risk is calculated for corporate bonds and loans are not collateralised. Let $h = 0, 1, \ldots, 7$ the Credit Quality Step (CQS) and let T_j be the lower bound of class of duration j (see Tables 4, 5 and 6), the $SCR_{spread,i}$ is :

$$SCR_{spread,i} = V_i(t)\phi_{hj}(D) \tag{6}$$

where $\phi_{hj}(D) = a_{hj} + b_{hj} * (D - T_j)$ is the SCR_{spread} per euro and it is a linear function of duration D, in this work ϕ_i denotes the SCR_{spread} per euro for i^{th} assets, thus the result for the entire portfolio is $SCR_{spread} = \sum_{i=1}^{m} V_i(t)\phi_i$. In Table 4 and 5, I report the coefficients used to calculate the spread risk.

		CQS assessment by a nominated ECAI i						
T_j	duration class	0	1	2	3	4	5	6
0	0-5	0	0	0	0	0	0	0
5	5-10	0.045	0.055	0.07	0.125	0.225	0.375	0.375
10	10-15	0.07	0.084	0.105	0.2	0.35	0.585	0.585
15	15-20	0.095	0.109	0.13	0.25	0.44	0.61	0.61
20	20-Inf	0.12	0.134	0.155	0.3	0.466	0.635	0.635

Table 4: Coefficients a_{ij} for spread risk, art.176(3) reg. (EU) 2015/35

		CQS assessment by a nominated ECAI i						
T_j	duration class	0	1	2	3	4	5	6
0	0-5	0.009	0.011	0.014	0.025	0.045	0.075	0.075
5	5-10	0.005	0.006	0.007	0.015	0.025	0.042	0.042
10	10-15	0.005	0.005	0.005	0.01	0.018	0.005	0.005
15	15-20	0.005	0.005	0.005	0.01	0.005	0.005	0.005
20	20-Inf	0.005	0.005	0.005	0.005	0.005	0.005	0.005

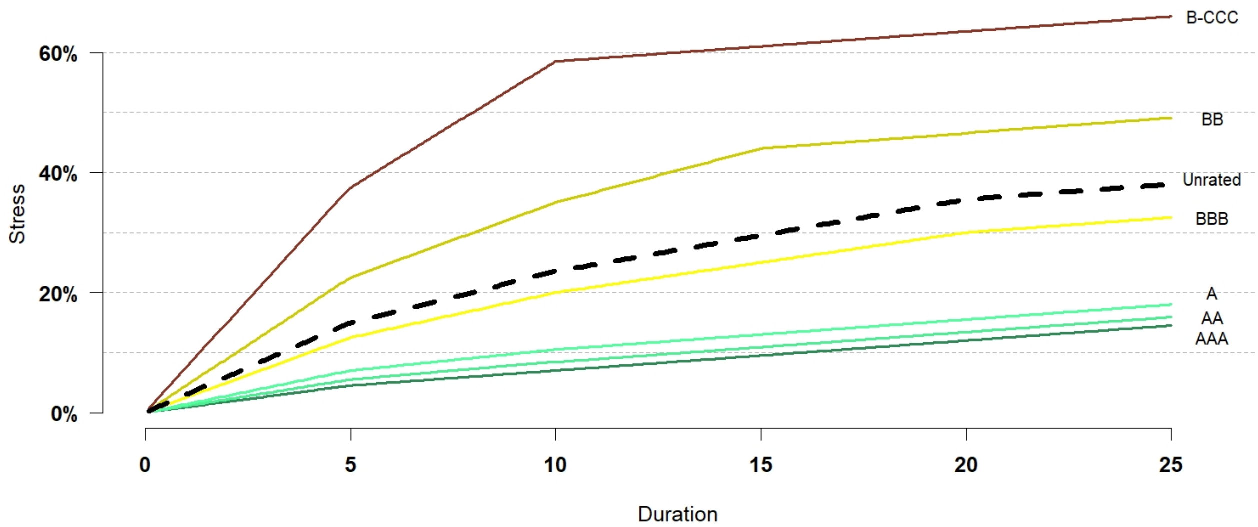
Table 5: Coefficients b_{ij} for spread risk, art.176(3) reg. (EU) 2015/35

Figure 7 shows that for unrated bonds (i.e. LM) the spread coefficients changes swiftly between h=3 (rating BBB) and h=4 (BB) for each modified duration. This is moderately relevant for the Italian market where in Q4-2022, 80.5% of corporates bonds have a BBB rating or better, 9% a BB rating or worse and 10.5% are unrated. Table 7 shows that, on average, the SCR_{spread} per euro is 0.0938, against 0.1462 in the unrated class, resulting in an average surplus charge for loans subject to spread risk of 0.0524.

T_j	duration class	a_{ij}	b_{ij}
0	0-5	0	0.03
5	5-10	0.15	0.017
10	10-20	0.235	0.012
20	20-Inf	0.355	0.005

Table 6: Coefficients a_{ij}, b_{ij} for spread risk, art.176(4) reg. (EU) 2015/35

Figure 7: Stress for spread risk.



Note: This figure illustrates the SCR_{spread} per euro of value asset for corporate bonds and loans (non-residential). The dot-line shows that loans have a risk capital charge greater than bonds with rating BBB but lower than rating BB.

Counterparty default risk module: in the calculation of the counterparty default risk, assets are classified into two types.[9] The mortgages on residential property shall be treated as type 2 exposures under the counterparty default risk and no a capital charge is applied to them for spread risk.[10] For this type of assets, the SCR for counterparty risk is calculated as $SCR_{default} = 0.15 * \max\left[V(t) - 0.8 * M(t), 0\right]$, as usual $V(t)$ is the value of the asset at time

[9]Article 189 of Regulation (EU) 2015/35.

[10]Article 191 of Regulation (EU) 2015/35.

CQS	Rating	weight (%)	Duration (y)	ϕ
1	AAA	0.0154	7.5162	0.0532
2	AA	0.0562	4.5668	0.0432
3	A	0.2707	5.2658	0.0618
4	BBB	0.4635	4.4989	0.1011
5	BB	0.0756	2.8010	0.1227
6	B	0.0134	2.4148	0.1739
7	CCC	0.0008	2.3711	0.1778
8	Unrated	0.1045	6.4409	0.1462

Table 7: Summary statistics of Corporate bonds at Q4-2022

t, while $M(t)$ is the value of mortgage. The ratio $V(t)/M(t)$ is usually called Loan to Value (LtV); under the standard formula the SCR for default risk depends on LtV, so we can write:

$$SCR_{default} = V(t) * 0.15 * \max\left[1 - 0.8/LtV, 0\right] \tag{7}$$

We note that the value of stress is zero if LtV is less than 80%, while it is 3% if LtV is equal to 100% and then it increases linearly. In the following, we use η_i to denote the $SCR_{default}$ per euro for i^{th} assets.

Remark: since spread risk and default risk are mutually exclusive, if an asset is included in the SCR module for spread risk, the corresponding default risk equals zero, and vice versa.

Let us consider a financial market where m asset classes are available and let $\omega = \{\omega_1, \ldots, \omega_m\}$ be the portfolio's share, $\sum_{i=1}^{m} \omega_i = 1$ with $\omega_i \geq 0$ for $i = 1, \ldots, m$, since short selling is not allowed. For assets class i we denote the rate of return with r_i and the return of portfolio with the weighted average $r(\omega) = \sum_{i=1}^{m} \omega_i r_i$. By $\psi = \{\psi_1, \ldots, \psi_m\}$, $\phi = \{\phi_1, \ldots, \phi_m\}$ and $\eta = \{\eta_1, \ldots, \eta_m\}$ we indicate the SCR per euro of asset respectively for interest, spread and default risk, so we have:

$$\begin{array}{lllllll} SCR_{int} & = & \sum_{i=1}^{m} V_i(t)\psi_i & = & V(t)\sum_{i=1}^{m} \omega_i\psi_i & = & V(t)\psi(\omega) \\ SCR_{spread} & = & \sum_{i=1}^{m} V_i(t)\phi_i & = & V(t)\sum_{i=1}^{m} \omega_i\phi_i & = & V(t)\phi(\omega) \\ SCR_{default} & = & \sum_{i=1}^{m} V_i(t)\eta_i & = & V(t)\sum_{i=1}^{m} \omega_i\eta_i & = & V(t)\eta(\omega). \end{array}$$

The total SCR cannot be obtained by a simple sum of single modules but it is calculated using the aggregation framework as reported in the Standard Formula following a Var-Cov approach.[11] The aggregation is made in two steps, where in the first step we obtain the SCR_{mkt} for market risk combining SCR_{int} and SCR_{spread} that in the standard formula have zero correlation, so the SCR_{mkt} per euro is $\sqrt{SCR_{int}^2 + SCR_{spread}^2}$. In the second step we aggregate the market and default risk module and we keep into account that the correlation by law is 0.25, so the result is $SCR = \sqrt{SCR_{mkt}^2 + SCR_{default}^2 + 2 * 0.25 * SCR_{mkt} * SCR_{default}}$, finally the SCR per euro of total assets can be written as a function of the portfolio's share ω:

$$\rho(\omega) = \sqrt{\psi(\omega)^2 + \phi(\omega)^2 + \eta(\omega)^2 + 0.5 * \eta(\omega)\sqrt{\psi(\omega)^2 + \phi(\omega)^2}} \tag{8}$$

B Data source

For European data comparison we use the balance sheet statistics according to Solvency II template S.02.01 at solo entity level and quarterly frequency, aggregated by country. For Italian companies we use the same balance sheets statistic, with detailed data by individual undertaking. We also use the full list of assets managed by Italian insurance companies from Solvency II quarterly templates S.06.01 and S.06.02.

[11] In the Var-Cov approach two or more risks are aggregated as if they were variances, i.e. let X_1 and X_2 two SCR relative two risk type and let τ the correlation then the aggregated SCR will be $\sqrt{X_1^2 + X_2^2 + 2\tau X_1 X_2}$.

	Country	Total Assets	Loans & mortgages	%	allocation% individuals	policies	other
1	FRANCE	2,223,445	52,160	2.35	2.54	8.37	89.08
2	GERMANY	2,047,953	100,018	4.88	53.92	1.47	44.61
3	ITALY	759,251	5,968	0.79	15.19	14.13	70.68
4	NETHERLANDS	368,752	88,937	24.12	65.26	0.01	34.73
5	DENMARK	345,105	5,236	1.52	2.44	0.00	97.56
6	SPAIN	265,267	1,893	0.71	1.95	4.50	93.55
7	IRELAND	214,202	7,374	3.44	0.18	0.20	99.62
8	BELGIUM	206,602	24,598	11.91	52.71	8.53	38.76
9	SWEDEN	165,060	8,059	4.88	0.00	0.14	99.86
10	NORWAY	154,671	12,770	8.26	24.53	0.00	75.47
11	LUXEMBOURG	124,120	4,328	3.49	6.40	1.44	92.15
12	AUSTRIA	112,167	4,907	4.37	2.22	0.69	97.09
13	PORTUGAL	37,387	627	1.68	24.67	0.46	74.88
14	FINLAND	33,961	766	2.25	0.04	0.01	99.95
15	POLAND	31,796	1,245	3.91	0.00	1.39	98.61
16	GREECE	14,859	134	0.90	8.48	22.05	69.47
17	CZECH REPUBLIC	14,705	500	3.40	0.00	0.68	99.32
18	LIECHTENSTEIN	13,438	962	7.16	0.00	5.74	94.26
19	MALTA	11,564	1,251	10.82	0.01	1.04	98.95
20	SLOVENIA	6,820	40	0.59	64.38	25.34	10.28
21	CROATIA	5,523	255	4.61	0.37	12.58	87.06
22	BULGARIA	4,737	158	3.33	2.94	1.34	95.72
23	ROMANIA	4,694	17	0.36	0.06	0.99	99.01
24	SLOVAKIA	4,294	117	2.73	0.05	3.11	96.84
25	HUNGARY	3,947	11	0.27	25.97	29.65	44.38
26	CYPRUS	2,797	72	2.58	2.29	4.88	92.83
27	ESTONIA	1,350	20	1.52	0.54	0.00	99.46
28	ICELAND	1,316	6	0.46	25.33	0.00	74.67
29	LITHUANIA	1,135	25	2.25	0.00	0.00	100.00
30	LATVIA	1,004	19	1.84	0.11	0.00	99.95

Table 8: Loans and Mortgages by country Q4-2022 (millions euro)

C Financial data and statistics on bonds

	Government - IT					Corporate - BBB					Loans and Mortgages	
	1-3	3-5	5-7	7-10	10+	1-3	3-5	5-7	7-10	10+	Retail	Residential
2016-12-31	-0.01	0.37	0.97	1.57	2.45	0.62	1.25	1.81	2.94	3.39	7.63	2.32
2017-03-31	0.02	0.65	1.31	1.96	2.85	0.42	1.14	1.62	2.72	3.41	8.13	2.54
2017-06-30	-0.00	0.59	1.24	1.85	2.81	0.36	0.98	1.62	2.40	3.11	8.49	2.47
2017-09-30	-0.11	0.47	1.11	1.82	2.81	0.24	0.80	1.37	2.14	2.88	8.51	2.41
2017-12-31	-0.04	0.54	1.15	1.75	2.78	0.29	0.72	1.29	1.90	2.21	8.05	2.27
2018-03-31	-0.25	0.29	0.91	1.52	2.44	0.04	1.01	1.57	2.24	2.55	8.38	2.24
2018-06-30	0.83	1.50	2.10	2.52	3.17	0.08	1.41	1.99	2.68	3.20	8.06	2.17
2018-09-30	1.36	2.14	2.65	2.94	3.47	0.77	1.47	2.07	2.64	2.96	8.28	2.16
2018-12-31	0.76	1.52	2.12	2.49	3.25	1.21	1.93	2.70	3.00	3.63	7.72	2.26
2019-03-31	0.55	1.27	1.85	2.27	3.14	0.78	1.23	2.00	2.21	2.71	8.19	2.17
2019-06-30	0.04	1.05	1.49	1.79	2.62	0.50	0.87	1.40	1.68	2.23	8.10	2.17
2019-09-30	-0.18	0.07	0.36	0.65	1.49	0.37	0.66	1.02	1.30	1.85	8.06	1.82
2019-12-31	0.04	0.44	0.80	1.18	2.06	0.32	0.72	1.08	1.36	1.80	7.60	1.78
2020-03-31	0.05	0.79	1.09	1.38	2.10	2.85	2.80	2.96	2.94	3.29	7.69	1.73
2020-06-30	0.11	0.50	0.80	1.13	1.89	1.31	1.41	1.63	1.74	2.28	7.50	1.61
2020-09-30	-0.15	0.01	0.41	0.71	1.40	0.08	0.95	0.13	1.37	2.04	7.89	1.61
2020-12-31	-0.40	-0.19	0.09	0.38	1.06	0.27	0.47	0.66	0.86	1.42	7.69	1.61
2021-03-31	-0.33	-0.01	0.18	0.50	1.24	0.17	0.54	0.75	1.09	1.53	7.98	1.72
2021-06-30	-0.32	-0.00	0.27	0.64	1.43	0.05	0.45	0.71	1.04	1.35	8.11	1.77
2021-09-30	-0.37	-0.05	0.30	0.68	1.45	0.03	0.42	0.70	1.02	1.38	8.03	1.74
2021-12-31	-0.15	0.24	0.59	0.95	1.68	0.25	0.71	0.98	1.24	1.53	7.64	1.74
2022-03-31	0.35	1.03	1.47	1.80	2.27	1.35	2.05	2.39	2.57	2.68	8.06	2.01
2022-06-30	1.42	2.12	2.60	3.06	3.52	3.66	4.38	4.68	4.89	4.94	8.34	2.37
2022-09-30	2.99	3.48	3.87	4.21	4.45	4.89	5.54	5.53	5.77	5.50	8.83	2.65
2022-12-31	3.44	3.80	4.16	4.46	4.84	5.26	5.54	5.59	5.45	5.25	9.22	3.36

Table 9: Annual return %.

D Main outcome results

	a: 1-3	b: 3-5	c: 5-7	d: 7-10	e: 10+	Tot
AT	0.08	0.05	0.11	0.04	0.30	0.58
BE	0.24	0.05	0.05	0.23	1.29	1.86
DE	0.96	0.13	0.13	0.13	0.78	2.13
ES	0.88	0.60	0.79	1.26	4.19	7.71
FR	0.94	0.24	0.35	0.52	2.20	4.26
IE	0.11	0.05	0.04	0.25	0.53	0.99
IT	19.21	7.73	10.69	13.77	23.47	74.88
NL	0.15	0.09	0.07	0.11	0.20	0.61
PT	0.04	0.07	0.24	0.24	0.73	1.33
Other	0.84	0.78	0.63	0.84	2.56	5.65
Tot.	23.46	9.80	13.10	17.39	36.25	100.00

Table 10: Composition of Government bonds held by Italian insurers at Q4-2021

	a: 1-3	b: 3-5	c: 5-7	d: 7-10	e: 10+	Tot
AT	0.10	0.07	0.09	0.12	0.19	0.57
BE	0.45	0.06	0.04	0.42	1.42	2.39
DE	1.20	0.22	0.20	0.28	0.58	2.48
ES	1.35	0.69	0.93	1.25	3.77	7.98
FR	1.63	0.42	0.46	0.50	2.63	5.65
IE	0.10	0.07	0.19	0.19	0.45	1.01
IT	21.93	9.33	10.92	12.02	17.04	71.24
NL	0.23	0.08	0.10	0.15	0.13	0.70
PT	0.07	0.08	0.25	0.36	0.49	1.26
Other	1.26	1.02	0.76	1.30	2.40	6.73
Tot.	28.33	12.03	13.95	16.60	29.11	100.00

Table 11: Composition of Government bonds held by Italian insurers at Q4-2022

	Country	a: 1-3	b: 3-5	c: 5-7	d: 7-10	e: 10+
1	AT	-0.62	-0.40	-0.29	-0.11	0.44
2	BE	-0.06	-0.44	-0.03	0.00	0.60
3	DE	-0.66	-0.53	-0.42	-0.27	0.00
4	ES	-0.51	-0.20	0.10	0.39	1.06
5	FR	-0.56	-0.37	-0.20	-0.00	0.68
6	IR	-0.55	-0.31	0.00	0.13	0.73
7	IT	-0.15	0.24	0.59	0.95	1.68
8	NL	-0.63	-0.46	-0.33	-0.19	0.15
9	PT	-0.52	-0.25	-0.01	0.28	0.82

Table 12: Return of Government bonds - Refinitiv datastream at Q4-2021

	Country	a: 1-3	b: 3-5	c: 5-7	d: 7-10	e: 10+
1	AT	2.85	2.84	3.01	3.21	3.20
2	BE	2.80	2.79	2.86	3.14	3.43
3	DE	2.57	2.54	2.52	2.53	2.58
4	ES	2.92	3.12	3.26	3.49	3.88
5	FR	2.84	2.82	2.87	2.97	3.30
6	IR	2.84	2.74	0.00	3.00	3.32
7	IT	3.44	3.80	4.16	4.46	4.84
8	NL	2.71	2.70	2.75	2.87	2.86
9	PT	2.88	2.95	3.09	3.41	3.80

Table 13: Return of Government bonds - Refinitiv datastream at Q4-2022

	a: 1-3	b: 3-5	c: 5-7	d: 7-10	e: 10+	Tot.
AAA	0.31	0.07	0.21	0.19	0.71	1.49
AA	2.45	1.25	0.70	0.58	0.78	5.76
A	6.73	6.22	4.24	4.39	2.96	24.53
BBB	13.80	12.06	8.54	7.75	4.79	46.95
BB	3.82	2.58	1.51	0.42	0.07	8.40
B	0.53	0.31	0.26	0.01	0.00	1.10
CCC	0.04	0.04	0.01	0.00	0.00	0.09
Unrated	3.39	2.61	2.47	1.72	1.49	11.67
Tot.	31.08	25.14	17.94	15.05	10.79	100.00

Table 14: Composition of Corporate bonds held by Italian insurers at Q4-2021

	a: 1-3	b: 3-5	c: 5-7	d: 7-10	e: 10+	Tot.
AAA	0.37	0.19	0.18	0.21	0.60	1.54
AA	2.42	1.21	0.68	0.76	0.55	5.62
A	8.11	6.83	5.48	3.97	2.65	27.04
BBB	17.20	12.81	7.77	5.39	3.15	46.32
BB	4.37	2.28	0.79	0.12	0.03	7.58
B	0.82	0.37	0.11	0.01	0.01	1.33
CCC	0.04	0.04	0.00	0.00	0.00	0.07
Unrated	3.13	3.01	1.67	1.37	1.32	10.49
Tot.	36.45	26.74	16.67	11.83	8.30	100.00

Table 15: Composition of Corporate bonds held by Italian insurers at Q4-2022

	Rating	a: 1-3	b: 3-5	c: 5-7	d: 7-10	e: 10+
1	A	-0.00	0.33	0.59	0.91	1.11
2	AA	-0.02	0.11	0.30	0.50	1.01
3	AAA	-0.02	-0.27	0.04	0.50	0.50
4	B	4.39	4.64	3.53	4.67	4.67
5	BB	0.21	2.75	0.34	2.69	2.69
6	BBB	0.25	0.71	0.98	1.24	1.53
7	CCC	1.18	7.83	7.88	7.92	7.92
8	Unrated	2.75	0.21	0.34	2.69	2.69

Table 16: Return of corporate bonds - Iboxx martik index at Q4-2021

	Rating	a: 1-3	b: 3-5	c: 5-7	d: 7-10	e: 10+
1	A	3.97	4.28	4.45	4.57	4.50
2	AA	3.47	3.68	3.72	3.74	3.95
3	AAA	-0.02	3.49	3.75	3.74	3.74
4	B	11.60	11.29	9.16	4.67	4.67
5	BB	8.89	9.54	10.81	6.74	6.74
6	BBB	5.26	5.54	5.59	5.45	5.25
7	CCC	18.90	23.10	16.53	13.02	13.02
8	Unrated	9.54	8.89	10.81	6.74	6.74

Table 17: Return of corporate bonds - Iboxx martik index at Q4-2022

	ω_1	ω_2	ω_3	ω_4	α	β	$r(\omega)$	$\rho(\omega)$
1	71.00	29.00	0.00	0.00	0.00		4.42	9.53
2	63.90	26.10	0.00	10.00	10.00	0.00	4.32	9.77
3	63.90	26.10	5.00	5.00	10.00	50.00	**4.61**	9.59
4	63.90	26.10	10.00	0.00	10.00	100.00	**4.90**	**9.43**
5	56.80	23.20	0.00	20.00	20.00	0.00	4.21	10.03
6	56.80	23.20	10.00	10.00	20.00	50.00	**4.80**	9.65
7	56.80	23.20	20.00	0.00	20.00	100.00	**5.38**	**9.38**
8	49.70	20.30	0.00	30.00	30.00	0.00	4.10	10.30
9	49.70	20.30	15.00	15.00	30.00	50.00	**4.98**	9.71
10	49.70	20.30	30.00	0.00	30.00	100.00	**5.86**	**9.38**
11	42.60	17.40	0.00	40.00	40.00	0.00	4.00	10.58
12	42.60	17.40	20.00	20.00	40.00	50.00	**5.17**	9.78
13	42.60	17.40	40.00	0.00	40.00	100.00	**6.34**	**9.42**

Table 18: Output of simulation in section 6, Q4-2022

		ω_1	ω_2	ω_3	ω_4	α	β	$r(\omega)$	$\rho(\omega)$	shadow cost	spread Gov.	spread Corp.
1	2016-12-31	76.86	18.14	5.00	0.00	5.00	100.00	2.12	9.00	6.35	5.18	4.24
2	2017-03-31	76.86	18.14	5.00	0.00	5.00	100.00	2.41	9.00	6.32	5.28	4.72
3	2017-06-30	76.93	18.07	5.00	0.00	5.00	100.00	2.28	9.00	6.80	5.68	5.38
4	2017-09-29	77.22	17.78	5.00	0.00	5.00	100.00	2.21	9.00	7.01	5.70	5.63
5	2017-12-29	77.22	17.78	5.00	0.00	5.00	100.00	2.10	9.00	6.72	5.27	5.84
6	2018-03-30	77.15	17.85	5.00	0.00	5.00	100.00	1.99	9.00	6.98	5.94	5.82
7	2018-06-29	77.22	17.78	5.00	0.00	5.00	100.00	2.82	9.00	5.78	4.89	4.86
8	2018-09-28	95.00	0.00	5.00	0.00	5.00	100.00	3.21	8.26	5.60	4.81	5.32
9	2018-12-31	76.04	18.96	5.00	0.00	5.00	100.00	2.84	9.00	5.35	4.47	4.09
10	2019-03-29	76.08	18.92	5.00	0.00	5.00	100.00	2.55	9.00	6.40	5.04	5.47
11	2019-06-28	95.00	-0.00	5.00	0.00	5.00	100.00	2.10	8.26	6.72	5.49	5.87
12	2019-09-30	32.17	62.83	5.00	0.00	5.00	100.00	1.19	9.00	7.43	6.57	6.21
13	2019-12-31	77.22	17.78	5.00	0.00	5.00	100.00	1.54	9.00	6.75	5.54	5.81
14	2020-03-31	27.31	67.69	5.00	0.00	5.00	100.00	2.91	9.00	4.69	5.59	4.40
15	2020-06-30	27.39	67.61	5.00	0.00	5.00	100.00	1.84	9.00	6.03	5.62	5.22
16	2020-09-30	47.74	47.26	5.00	0.00	5.00	100.00	1.30	9.00	6.97	6.49	5.85
17	2020-12-31	47.71	47.29	5.00	0.00	5.00	100.00	0.90	9.00	7.22	6.62	6.27
18	2021-03-31	47.72	47.28	5.00	0.00	5.00	100.00	1.01	9.00	7.48	6.74	6.45
19	2021-06-30	77.22	17.78	5.00	0.00	5.00	100.00	1.09	9.00	7.65	6.68	6.75
20	2021-09-30	77.22	17.78	5.00	0.00	5.00	100.00	1.11	9.00	7.55	6.59	6.65
21	2021-12-31	77.22	17.78	5.00	0.00	5.00	100.00	1.34	9.00	6.91	5.96	6.11
22	2022-03-31	55.42	39.58	5.00	0.00	5.00	100.00	2.30	9.00	6.04	5.79	5.38
23	2022-06-30	29.75	65.25	5.00	0.00	5.00	100.00	4.10	9.00	3.96	4.82	3.40
24	2022-09-30	29.75	65.25	5.00	0.00	5.00	100.00	5.17	9.00	3.28	4.38	3.33
25	2022-12-31	29.75	65.25	5.00	0.00	5.00	100.00	5.43	9.00	3.67	4.38	3.97

Table 19: Shadow cost in figure 4

WORKING PAPERS PUBLISHED

N. 1. Il Ramo r.c. auto: raffronto tra l'Italia e alcuni paesi della UE su premi, sinistri e sistemi risarcitori del danno alla persona, di Lino Matarazzo (ottobre 2014).

N. 2. La riforma della CARD: costi dei sinistri e incentivi all'efficienza nel risarcimento diretto r.c. auto, di Riccardo Cesari, Marina Mieli e Arturo Valerio (maggio 2015).

N. 3. Dal chain ladder al modello di Merz e Wüthrich: derivazione completa del modello di volatilità della riserva sinistri in orizzonte annuale, di Stefano Cavastracci (giugno 2015).

N. 4. Redditività e ciclo del settore assicurativo italiano prima e durante la crisi, di Fabio Farabullini (novembre 2015).

N. 5. Seminari per i dieci anni del codice delle assicurazioni private, di Riccardo Cesari (Prefatore), Enrico Galanti (Coordinatore), Sandro Amorosino, Roberto Caponigro, Stefania Ceci, Luigi Farenga, Antonio Longo, Francesco Mauro, Gustavo Olivieri, Andrea Pezzoli, Salvatore Providenti, Umberto Santosuosso, Dario Zamboni (maggio 2016).

N. 6. Il diritto nella società contemporanea, di Ottavio De Bertolis (novembre 2016).

N. 7. Duration, convexity and the optimal management of bond portfolios for insurance companies, di Riccardo Cesari e Vieri Mosco (febbraio 2017).

N. 8. Il nuovo Regolamento IVASS sull'accesso agli atti - La distribuzione Assicurativa - Il gruppo dopo Solvency II, di E. Galanti, M. Binda, M. L. Cavina, M. Fodale, N. Gentile, R. Giay, P. Marano, P. Mariano, S. Marzucchi, A. Police, A. Serino, V. Troiano (Aprile 2017).

N. 9. Modello overdispersed Poisson: formula chiusa per la stima GLM della volatilità one year della riserva sinistri, di Stefano Cavastracci e Agostino Tripodi (giugno 2017).

N. 10. No news is good news: moral hazard in oligopolistic insurance markets, di Marco Cosconati (18 aprile 2018).

N. 11. Riforma del sistema europeo delle Autorità di controllo. Governance imprese assicurative. Gestione crisi nel settore bancario e assicurativo, di S. Butera, F. Buzzichelli, R. Cercone, A. Corinti, S. De Polis, C. Di Noia, S. Fortunato, E. Galanti, F. Montemaggiori, M. Morvillo, M. O. Perassi, P. Rosatone, V. Santoro, S. Scarcello, E. Serata, M. Siri (maggio 2018).

N. 12. Valore aggiunto e profittabilità delle compagnie italiane: cosa conta realmente?, di Leandro D'Aurizio (marzo 2019)

N. 13. Calamità naturali e coperture assicurative: valutazione dei rischi e policy options per il caso italiano, di Riccardo Cesari e Leandro D'Aurizio (luglio 2019)

N. 14. Defiscalizzare la r.c. auto: come e perché, di Riccardo Cesari e Antonio R. De Pascalis (ottobre 2019)

N. 15. Two simple models of insurance fraud, di Riccardo Cesari (gennaio 2021)

N. 16. La governance dell'Artificial Intelligence nel settore assicurativo tra principi etici, responsabilità del board e cultura aziendale, di Diana Capone (febbraio 2021)

N. 17. The effect of uncertainty on the car insurance market: evidence from the COVID-19 shock, di Marco Cosconati e Viviana Medori (agosto 2021)

N. 18. Le relazioni tra banche e assicurazioni in Italia, di Federico Apicella, Leandro D'Aurizio, Raffaele Gallo, Giovanni Guazzarotti (settembre 2021)

N. 19. Test di Benford sulla qualità dei dati, di Riccardo Cesari (ottobre 2021)

N. 20. Proposta di una tabella unica nazionale per il risarcimento del danno non patrimoniale per lesioni di non lieve entità, di Riccardo Cesari, Alessandro Costantini, Antonio Rosario De Pascalis, Elio Di Jeso, Marco Leotta (novembre 2021)

N. 21. Le competenze assicurative e finanziarie degli italiani a confronto, di Riccardo Cesari e Leandro D'Aurizio (dicembre 2021)

N. 22. Donne, board e imprese di assicurazione, di Diana Capone, Flaminia Montemaggiori e

N. 23. An introduction to Poisson processes and their generalizations, di Enzo Orsingher, Riccardo Cesari, Vieri Mosco (febbraio 2022)

N. 24. Insurance Fraud Detection: A Statistically-Validated Network Approach di Michele Tumminello, Andrea Consiglio, Pietro Vassallo, Riccardo Cesari e Fabio Farabullini (ottobre 2022)

N. 25. Sul calcolo del danno patrimoniale da perdita di capacità lavorativa: aspetti attuariali e applicativi, di Riccardo Cesari (novembre 2022)

N. 26. A Risk Dashboard for the Italian insurance sector, di Leandro D'Aurizio e Silvia Sacco (maggio 2023)

N. 27. Reassessing the Italian seismic hazard using soil classification, di Riccardo Cesari e Leandro D'Aurizio (settembre 2023)

N. 28. Il risarcimento in forma di rendita e la sua replica con titoli di Stato , di Riccardo Cesari (febbraio 2024)