ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

O5-A1

First case study report

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Case Study Report

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Change History

Version	Date	Author(s)	Changes
0.1	July 3, 2015	Umberto Cherubini	Written presentation of the case study for the first IP (Bologna, 5-18 July 2015)
0.2	September 30, 2015	Rossella Agliardi	First draft of O5/A1
0.3	December 10, 2015	Rossella Agliardi	Second draft of O5/A1

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Content

1. Case Structure

In this paper we outline and summarize the results of the case study that has been examined during the pilot intensive programme (IP) offered at the University of Bologna within the International Project **INTQUANT (**Creating an International Semester for Master Programmes in Quantitative Finance), Funding Scheme: Erasmus+ Strategic Partnerships (Key Action 2).
This case study has been proposed in cooperation with the local industry partner, Unipol Financial Group S.p.a. The assigned problem has been studied by five teams, each consisting of four students from the partner universities **(**University of Applied Sciences bfi Vienna, University of Bologna, University of Economics in Katowice and Alexandru Ioan Cuza University of Iasi).

1. Synopsis/Executive Summary

The proposed case study examines the problem of risk management addressed by an insurance company, in the year in which Solvency II will come into place [1]. The situation that is mimicked during the IP is the plan of the Insurance Company to set up a control risk unit that must be in charge of measuring risk, satisfy regulatory compliance requirements, and provide suggestions for effective risk management solutions.
As the Insurance Company is particularly active in life insurance policies, the massive problem for its business line is to measure and manage the funds collected from the clients and invested, versus the negative cash flows for the payment of benefits. Its plan is to start building its Risk Management Unit (RMU) from the market risk. For this reason it decided to disclose one of its portfolios, and to ask the five groups of the INTQUANT project for proposals concerning a best practice line for market risk management.

The main mission of the RMU would be to measure the several sources of risk to which the portfolio is exposed because of market movements. The analysis should take into

[1] Solvency II implementing measures take the form of Delegated Acts, Regulatory Technical Standards and Implementing Technical Standards and will apply to insurers. The European Commission requested advice from EIOPA on implementing technical standards. EIOPA issued a draft Implementing Technical Standards (ITS) in October 2014 and a second set of ITS on 3 July 2015. Further ITS will follow and are expected to be adopted by the European Commission. On 30 September 2015 the European Commission has amended some parts of the Solvency II implemented rules, which were laid down on 10 October 2014.

account both the impact of market movements on future net cash flows and the impact on present value of assets and liabilities. On top of that, the RMU should also compute the solvency capital ratio according to the rules of Solvency II.

The case is designed to provide a context for an introduction to a typical problem in a risk management unit within an important multi-business insurance company, in this case, facing both a problem of ALM (assets and liabilities management) and risk management, that is the evaluation of the impact of a change in market values in an assigned portfolio. Students are invited to identify the risk factors to which the portfolio is exposed, to provide a Mark-to-Market calculation, to estimate the total risk exposure with respect to the relevant risk measures and to perform a check of the financial "health" of the portfolio.
Students are also asked to identify the negative gaps in the portfolio and propose corrections and restructuring of the portfolio; they are also invited to make recommendations on possible hedging strategies and to perform alternative stress-test analyses on the MtM value of the portfolio.

The case discussion can generate some tension with respect to the most appropriate method for pricing the bonds and the other financial securities throughout quoted prices, for identifying the risk factors to which each asset is exposed and aggregating the risks, and on how to design one's own stress-test scenario.

The case materials afford students to cope with the problem of designing tailored treatments to insurers' investments in interest rate sensitive instruments, with the Solvency Capital Requirement in view. In particular, students are expected to:

- become familiar with the methods for computing the Mark-to-Market value of bonds and interest rate sensitive derivatives, by constructing an appropriate interest rate term structure;
- experiment the effect of the relevant risk metrics in a real-world problem;
- learn how to build a stress test scenario for the risk analysis of asset and liabilities of an insurance company with BSCR in view;
- critically assess their findings by comparing alternative methodologies and procedures of market risk analysis.

2. Short history and company overview/ Background

UnipolSai Assicurazioni S.p.A. is the multi-business insurance company of the Unipol Group, an Italian leader in Non-Life business, particularly in vehicle liability insurance. The

company currently operates through five divisions (Unipol, La Fondiaria, Sai, Nuova MAA and La Previdente). UnipolSai is the second insurance company on the Italian market, classified among the top ten in Europe, registering a direct insurance income of €16bn as of 31 December 2014 (of which € 8.4bn are Non-Life and €7.6bn are Life Business). It adopts an integrated offer strategy, providing a full range of insurance and financial products, and is particularly active in supplementary social security and health sectors. The core business is complemented by presence in the banking sector, real estate sector and other diversified activities. It serves over 16 million customers thanks to a vast network of agencies.

The financial engineering team of UnipolSai is involved in a wide range of activities, among which the development of an in-house platform for the pricing and tracking of structured interest rate products and interest and equity derivatives. This includes writing libraries for calibration to the market data, pricing and sensitivity analysis of the portfolio. Among its tasks it has to develop an internal model to calculate the capital requirement required by Solvency II.

3. Body of the analysis

The case study aims at highlighting a specific facet of the problems faced by a risk management unit of an insurance company, in view of an accomplishment of Solvency II measures. The primary objective for valuation - as set out in the EC Directive - requires an economic, market-consistent approach to the valuation of assets and liabilities, that is, according to the risk-based approach of Solvency II, when valuing balance sheet items on an economic basis, insurance and reinsurance undertakings have to consider the risks that arise from a particular balance sheet item, using assumptions that market participants would use in valuing the asset or the liability. At present, a set of technical specifications has been issued to provide an implementation consistent with the principles of Solvency II, although they might not fully reflect the final European Commission's implementing measures, as the draft delegated acts remains subject to change.
In any case, the going concern is to set up a valuation framework that is consistent with the international accounting standards and regulations as adopted by the European Commission.
In principle, Solvency II provides a range of methods to calculate the Solvency Capital Requirement (SCR) which allows to choose a method that is proportionate to the nature, scale and complexity of the risk to be measured: they might be, at one extreme, full internal models or, at the other extreme, standard formulas with simplifications. The Basic

Solvency Capital Requirement (BSCR) is the Solvency Capital Requirement before any adjustments, combining capital requirements for six major risk categories. In this case study, the focus is on the market risk arising from interest rate sensitive instruments, because the disclosed asset sub-portfolio of the Insurance Company mainly consists of bonds, both fixed-income and variable-income bonds, mainly government bonds, and some interest rate derivatives.
Although the data for the synthetic portfolio provided in this case study (see Appendix A1 and A2) mimics a real sub-portfolio of the Unipol Group, in view of an imperfect identity, in the sequel we will refer to the Insurance Company as ABC Insurance Company.

The case to study can be described as follows.

Title: ABC INSURANCE IS HEADING FOR RISK MEASUREMENT IN THE SOLVENCY II ERA

Problem description
The ABC Insurance Company has a portfolio (a sub-portfolio, actually, that the company would like to provide in order to select and train the RMU) that is made of three elements:

- Bonds
- Derivatives
- Liabilities

Bonds are for 393 millions exposed to the Italian government bond markets, and for 145 millions to banks. The exposure to Italian sovereign bonds is all at fixed rate; both zero coupon bonds and BTPs. BTPs pay fixed rate coupons paid semiannually, a repayment of the principal at maturity (so called *bullet bonds*). The exposure-to-bank bonds are all floating rate notes. All floating notes are plain vanilla (including a spread), except the Rabobank one that will require particular attention.
The derivatives portfolio consists of plain vanilla swap contracts (fixed against variable) for an overall amount of 110 millions. More precisely, ABC Insurance pays fixed in the contract with JP Morgan (4.5% fixed rate, 50 millions nominal) and receives fixed from Barclays (3% fixed rate, 60 millions nominal). With both the counterparties in these contracts the ABC Insurance company has a Credit Support Annex agreement. Under these agreements, the value of the contract is marked to market every day and the party that is out of the money (so the party for which the contract has negative value) posts collateral with the other party.

Finally, ABC Insurance has a stream of liabilities to face. These liabilities are assumed to be due at the end of the year, when they are reported in the balance sheet.

ABC Insurance has both a problem of ALM (assets and liabilities management) and risk management that is the evaluation of the impact of a change in market values. It would like to have a clear, albeit exhaustive, check of the financial "health" of the portfolio. In practice, ABC Insurance wants: i) a list of the risk factors to which it is exposed; ii) a representation of the exposure and iii) the relevant measures of risk.
The selection committee in charge of selecting the RMU unit of ABC Insurance will evaluate the analysis proposed by five teams, where each team will work on the proposed case by choosing its own methodologies and offering its own set of solutions.

4. Questions for discussion

1) Compute the MtM value of the portfolio (considering the yield curve and spreads). We do not have traded spreads for ABC Insurance, use educated guess.
2) A general description of the ALM stance of the portfolio. Check duration and convexity, and browse Reddington theorem and similar to see what that means.
3) Describe the risk factors to which the portfolio is exposed, and design a reporting (cash flow mapping) of the exposures to each risk factor.
4) Compute VaR and ES with respect to every risk-factor and the aggregated value (undiversified)
5) Perform your own stress-test analysis on the MtM value of the portfolio (increase in interest rates? Increase in BTPs spreads?).
6) Design a hedge against an increase in interest rate in one year.

5. Conclusion/recommendations

The analysis has been carried on by five international teams, each team working on the main questions of the above-described problem. Each team was free to select an appropriate methodology and has provided its own set of solutions. The main conclusions can be summarized as follows.

The MtM value of the portfolio obtained throughout different methods (depending on the chosen market quotes, approach for constructing the yield curve and considering the spreads, numerical code for implementation, pricing method for the structured product)

does not vary significantly across the working teams. A similar conclusion applies to the computation of the duration of the portfolio. Significant differences are obtained whether the risk measures are computed throughout a historical method or a parametric one.
The analysis identified some negative gaps in the portfolio in terms of liquidity and duration, and proposed some adjustments and recommendations.
Stress testing has been performed with the basic scenarios of Solvency II in view: depending on the methods used in any specific issue and stage of the analysis, the results were not unanimous.

6. References

EIOPA – 14/209, Technical Specification for the Preparatory Phase (Part 1) , 30 April 2014

D. Brigo and F. Mercurio, Interest rate models—theory and practice, Springer Verlag, Berlin, 2006

U. Cherubini, G. Della Lunga, Stress-testing techniques and VaR measures: a unified approach. Rivista di Matematica per le Scienze Economiche e sociali (1999), 22, 77-99

7. Appendices

Here below the original data that relates to the study are reported.

Table A1, A2, A3. Synthetic portfolio for the case study.

Table A1. Bond Portfolio

SECURITY_NAME Name	MATURITY Maturity	COUPON_RT Coupon	ISSUER Iusser	COUNTRY_FULL_NAME Nationality Iusser	Notional
BOTS 0 01/14/16	14/01/2016	0	BUONI ORDINARI DEL TES	ITALY	3.000.000
BOTS 0 06/14/16	14/06/2016	0	BUONI ORDINARI DEL TES	ITALY	15.000.000
BTPS 5 1/4 08/01/17	01/08/2017	5,25	BUONI POLIENNALI DEL TES	ITALY	30.000.000
BTPS 4 1/2 03/01/19	01/03/2019	4,5	BUONI POLIENNALI DEL TES	ITALY	45.000.000
BTPS 4 09/01/20	01/09/2020	4	BUONI POLIENNALI DEL TES	ITALY	30.000.000
BTPS 8 1/2 12/22/23	22/12/2023	8,5	BUONI POLIENNALI DEL TES	ITALY	80.000.000
BTPS 1 1/2 06/01/25	01/06/2025	1,5	BUONI POLIENNALI DEL TES	ITALY	100.000.000
BTPS 1.65 03/01/32	01/03/2032	1,65	BUONI POLIENNALI DEL TES	ITALY	5.000.000
BTPS 4 02/01/37	01/02/2037	4	BUONI POLIENNALI DEL TES	ITALY	50.000.000
BTPS 3 1/4 09/01/46	01/09/2046	3,25	BUONI POLIENNALI DEL TES	ITALY	35.000.000
UCGIM 0 02/19/20	19/02/2020	3m Euribor + 100bps	UNICREDIT SPA	ITALY	50.000.000
BNP 0 03/03/18	03/03/2018	3m Euribor + 60bps	BNP PARIBAS	FRANCE	60.000.000
ISPIM 0 02/01/33	01/02/2033	3m Euribor + 90bps	INTESA SANPAOLO SPA	ITALY	10.000.000
RABOBK 0 12/16/25	16/12/2025	6m Euribor + 20 bps; cap at previous coupon +25 bps	RABOBANK NEDERLAND	NETHERLANDS	25.000.000

Table A2. Derivatives

Name	Counterpart	Payer leg	Receiver leg	Maturity	CSA	Notional
swap 1	JP Morgan	4,50%	6m Euribor	30/06/2028	Y	50.000.000
swap 2	BARCLAYS	3%	6m Euribor	15/01/2020	Y	60.000.000

Table A3. Liabilities

Liabilities	Cash flow	Liabilities	Cash flow
31/12/2015	0	31/12/2031	-
31/12/2016	15.000.000	31/12/2032	2.000.000
31/12/2017	25.000.000	31/12/2033	5.500.000
31/12/2018	45.000.000	31/12/2034	-
31/12/2019	30.000.000	31/12/2035	-
31/12/2020	62.000.000	31/12/2036	-
31/12/2021	-	31/12/2037	35.000.000
31/12/2022	3.000.000	31/12/2038	-
31/12/2023	40.000.000	31/12/2039	-
31/12/2024	2.500.000	31/12/2040	-
31/12/2025	90.000.000	31/12/2041	-
31/12/2026	-	31/12/2042	-
31/12/2027	-	31/12/2043	-
31/12/2028	-	31/12/2044	-
31/12/2029	-	31/12/2045	-
31/12/2030	-	31/12/2046	25.000.000

Table A4. Up and down scenarios.

Maturity t (years)	Relative change sup(t)	Relative change sdown(t)
1 or shorter	70%	-75%
2	70%	-65%
3	64%	-56%
4	59%	-50%
5	55%	-46%
6	52%	-42%
7	49%	-39%
8	47%	-36%
9	44%	-33%
10	42%	-31%
11	39%	-30%
12	37%	-29%
13	35%	-28%
14	34%	-28%
15	33%	-27%
16	31%	-28%
17	30%	-28%
18	29%	-28%
19	27%	-29%
20	26%	-29%
90 or longer	20%	-20%

2. Teaching Note Structure

1. Synopsis

The purpose of this case study is to mimic the work within a control risk unit of a big Insurance Company, whose assignment is to measure market risk in view of the international regulatory standards and compliance requirements, in the year in which Solvency II will come into place, and with the purpose of suggesting some effective solutions for a best practice line in market risk management.

As the Insurance Company is particularly active in life insurance policies, the massive problem for its business line is to measure and manage the funds collected from the clients and invested, versus the negative cash flows for the payment of benefits. Thus the case combines a problem of ALM with a risk management assignment.

The study can be briefly described as follows. The Insurance Company discloses one of its portfolios. The analysis should consider both the impact of market movements on future net cash flows and on present value of assets and liabilities. Then the relevant risk measures should be applied with the Solvency Capital Requirement (SCR) of Solvency II in view. The disclosed portfolio consists of bonds, derivatives and liabilities, and the data are provided in the Appendix of Section 1 (see Tables A1, A2, A3). The bond component of the portfolio is represented in the Figure 1, showing that the largest exposure is to the Italian government bonds. The portfolio has a derivative component too, consisting of plain vanilla swap contracts with JP Morgan and Barclays. Finally, the Insurance Company has a stream of liabilities to face which are due at the end of the year, when they are reported in the balance sheet. The details for all the components of the portfolio are reported in Section 1 and its Appendix (Table A1, A2, A3).

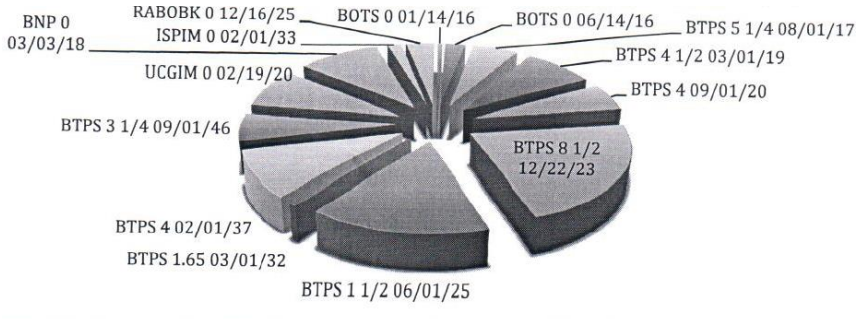

Figure 1. Bond component of the portfolio

The aim of this case study is to check of the financial "health" of the portfolio. In particular, to identify the factors of risk exposure and represent the risk exposure, to compute the

MtM value of the portfolio and calculate the aggregate risk under the relevant risk measures, to perform a stress-test analysis by focusing mainly on market risk.

2. Topical Area

The area of research for the case study can be described, in a broad sense, as follows: advanced methods for modeling the term structure of interest rates: impact for stress testing in financial and insurance institutions.

3. Teaching objectives

The case focuses on developing the following teaching objectives:

- to gain a in-depth understanding of the methods for modeling the term structure of interest rates and for computing the Mark-to-Market value of (structured) bonds and of interest rate derivatives;
- to build student judgment on how to appropriately perform specific calibrations for risk factors to be applied on different types of insurers' investments;
- to explore the effect of various risk metrics;
- to experiment how to build a stress test scenario for the risk analysis of asset and liabilities of an insurance company;
- to become aware of the standard approach to calculate the Solvency Capital Requirement, at least for the market risk embedded in the specific portfolio under consideration.

Additionally, the work on the case can contribute to achieve some general teaching objectives, such as the ability to:

- summarise case findings in a team report, present and defend these in a clear and effective way;
- critically asses both one’s own and other teams’ case reports during the presentation phase;
- work in an international team environment and use intercultural creativity to achieve an agreed outcome.

4. Student Reading Assignment

ABC INSURANCE IS HEADING FOR RISK MEASUREMENT IN THE SOLVENCY II ERA

5. Student Study Questions

1. What is the MtM value of the portfolio (considering the yield curve and spreads)?
2. rovide a general description of the ALM stance of the portfolio. Check duration and convexity, and browse Reddington theorem and similar to see what that means.
3. What are the risk factors to which the portfolio is exposed?
4. Compute VaR and ES with respect to every risk-factor and the aggregated value (undiversified)
5. Perform your own stress-test analysis on the MtM value of the portfolio
6. Design a hedge against an increase in interest rate in one year.

6. Suggested Teaching Plan for *60*-Minutes Class

(10 min.) Why study this case?

(10 min.) What are the big issues Unipol is dealing with today?

(20 min.) What does the globalization of regulation mean for an Insurance Company?
(20 min.) Assume that you are a financial engineer working for this Insurance Company and your task is to report the financial «health» of the company. What does your CFO expect to find on his desk ?

- MtM value of the assigned portfolio
- VaR and expected shortfall of the portfolio at different confident level and different time horizons
- Stress-test analysis on the MtM value of A-L as a result of two pre-defined shocks of the market data (scenario up and scenario down).

7. Discussion Questions and Analysis/Student Response

This section gives details information to the instructor on how to address the main questions. This section can be seen as a roadmap to the instructor.

1. *What is the MtM value of the portfolio (considering the yield curve and spreads)?*

Asking students to compute MtM value of the assigned portfolio is an excellent starting point to find out the varying levels of knowledge of interest rate models and interest rate sensitive financial products. Students have to decide how to produce the implied spot rates

and the corresponding discount factors to be employed. They might bootstrap the zero curve and the forward curve from the market data or use a stochastic model and calibrate it to the market data. Each team will have to take advantage of its internal financial and numerical expertise and will have to discuss about the accuracy of its approach, on how to deal with the lack of liquidity of some bonds and how to model the embedded credit risk. The instructor might suggest a stylized way to model credit risk, as the main focus of the case is on market risk.
As the portfolio includes a structured bond that does not allow for a simple pricing formula, its valuation takes the form of a (numerical) sub-problem.
Finally, students will realize that calculations for interest rate swaps differ in the objective: pricing an at-market (or par) swap, valuing an off-market swap, and inferring the forward curve that is consistent with a sequence of at-market swaps.
The instructor could suggest to compute the MtM of a swap with or without CSA (= Credit Support Annex).

We suggest that the students should be free to select the data sources for market quotes, the computational method to interpolate Euribor rates and the forward rates, the method for valuing the several financial products, how to handle credit risk, etc.

2. *Provide a general description of the ALM stance of the portfolio. Check duration and convexity, and browse Reddington theorem and similar to see what that means.*

The instructor discusses the methods for providing a clear picture of the ALM stance of the portfolio. Then students are asked to compute the duration and convexity for the several components of the portfolio, which is a good exercise in view of the variety of products.
Then for the overall portfolio duration one weights the bonds by their prices; as for the liabilities one sums the product between the cash flows of each liability and their times of life.
The analysis helps identifying some negative gaps in the portfolio in terms of liquidity and duration. Students are invited to propose their own solutions regarding possible adjustments and to offer recommendations to the insurance undertaking.

3. *What are the risk factors to which the portfolio is exposed?*

A preliminary discussion identifies all the risk factors to which each component of the portfolio is exposed. Then a parsimonious set of risk factors is selected. Students are invited to design a reporting (cash flow mapping) of the exposures to each risk factor. Then the class can move on to considering the appropriate risk metric.

4. *Compute VaR and ES with respect to every risk-factor and the aggregated value (undiversified)*

The Solvency II Framework Directive specifies that the SCR corresponds to the Value-at-Risk of the basic own funds of an insurance or reinsurance undertaking subject to a confidence level of 99.5% over a one-year period. The parameters and assumptions used for the calculation of the SCR reflect this calibration objective and to ensure that the different modules of the standard formula are calibrated in a consistent manner, this calibration objective applies to each individual risk module.
For the aggregation of the individual risk modules to an overall SCR, linear correlation techniques are applied.
The students are asked to compute the relevant risk measures for the portfolio under consideration. They can be invited to experiment several confidence levels and time horizons.
A discussion may concern the issue of risk aggregation. They are asked to compute undiversified risk, but in the case they pursue alternative aggregations, they can appreciate the effect of diversification.

5. *Perform your own stress-test analysis on the MtM value of the portfolio*.

The instructor introduces the target and several methods of stress-testing, so that students have an overview on the topic. In the case under study, the analysis might eventually be confined to computing the change of the MtM A- L as a result of two pre-defined shocks to the market data (scenario up and scenario down). The capital requirement for interest rate risk is determined as the result of two pre-defined scenarios:

$$MktintUp = \Delta BOF|up$$

$$MktintDown = \Delta BOF|down$$

where $\Delta BOF|up$ and $\Delta BOF|down$ are the changes in the net value of asset and liabilities due to re-valuing all interest rate sensitive items using altered term structures upward and downward. The stress causing the revaluations is instantaneous.
In the case of negative initial interest rates, the “stressed” 15-year interest rate $R(15)$ in the upward stress scenario is determined as

$$R(15) = R_0(15) + ass(R_0(15))*0.33$$

and in the downward stress

$$R(15) = R_0(15) - ass(R_0(15))*0.27$$

Irrespective of the above stress factors, the absolute increase of interest rates in the upward scenario at any maturity should at least be one percentage point.

However, students can be invited to experiment alternative scenarios. For example, one question at hand is whether to increase only the interest rates or to increase the BTPs spreads as well. Furthermore, the effect of non-flat changes of the term structure can be investigated. In any case, students should be made aware that the approach taken for the recalculation of the best estimate to assess the impact of the stress should be consistent with the approach taken in the initial valuation of the best estimate.

6. *How to hedge against an increase in interest rate in one year?*

Students are invited to design some possible hedges against the increase in interest rates. They are invited to compare and discuss some techniques to implement a hedge, among which, short-selling, using swaptions, inverse bond ETFs, etc.
Finally, hedging strategies could be contrasted to portfolio restructuring aiming at mitigating the risk of interest rate movements, by discussing the costs and benefits of both behaviours.

8. Conclusions

The results of the case study highlighted raised and highlighted the main issues involved in risk management, not only for the insurance industry, but also for financial institutions in general. In particular, the students are exposed, like professionals are, to the dualism of duties of risk management and compliance. Measuring and managing risk is different and, in some cases, may also be in conflict with the duty of complying with the measures required by the regulation. Moreover, the students, divided in groups, can have a practical evidence of the relevance of model risk. In fact, by cross checking the risk measurement results achieved with different models by the different groups, the students witness, in this simple case study, the huge difference that may result in the measurement of risk of the same portfolio. In the global regulation debate in the banking industry, the same issue has triggered the revision of the market risk regulation, in what is called the Fundamental Review of the Trading Book (FRTB), or Basel IV.

3. Case study materials

Suggested readings for the specialization track

EIOPA – 14/209, Technical Specification for the Preparatory Phase (Part 1) , 30 April 2014

U. Cherubini, G. Della Lunga, Stress-testing techniques and VaR measures: a unified approach. Rivista di Matematica per le Scienze Economiche e sociali (1999), 22, 77-99

Preliminary readings

Participating students will have to prepare themselves prior to work on the case. Students should have a notion of the basic definitions of interest rates (short rate and forward rate dynamics, market examples), coupon bonds, yield, yield-to-maturity, term structure, swaps, caps and floors. A good knowledge of some general concepts in finance, such as arbitrage pricing and martingale methods, is needed as well.

For an introduction the following texts are recommended to the students with limited exposure to the above-mentioned notions:
D. Filipovic, Term-structure models: a graduate course, Springer Verlag , 2009
M. Musiela and M. Rutkowski, Martingale methods in financial modelling, Springer Verlag, 2005

A more advanced text on interest rate models is:
D. Brigo and F. Mercurio, Interest rate models—theory and practice, Springer Verlag, Berlin, 2001 or 2006 (2nd edition)

Case study method

Ellet, W. (2007). *The Case Study Handbook: How to Read, Discuss and Write Persuasively About Cases*. Boston: Harvard Business Review Press.

Shapiro, B. (2014). *Hints for Case Teaching.* Boston: Harvard Business Publishing. Retrieved from [http://hbsp.harvard.edu/he-main/resources/documents/web-files/M00016_Hints_for_Case_Teaching_Brochure.pdf]

Materials for the case study

Spreadsheet for the disclosed asset portfolio and liabilities under study.
Additional data on: the Euribor and Swap curve; bond volatilities; the up and down scenarios under the Basic Solvency Capital Requirement

Supplementary materials
Supplementary MatLab codes are provided for students with limited exposure to the calibration of stochastic models for interest rates (e.g. Vasicek model).