An investigation of the Volatility Adjustment

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Abstract

We use market data to reconstruct the Volatility Adjustment of different countries on a monthly basis. The Volatility Adjustment aims at capturing the non fundamental (or credit quality) components of the spread of bonds detained by insurance companies. We show that the country specific component of the Volatility Adjustment strongly depends on the weights used to compute it and that its drivers are mostly provided by the risk appetite worldwide.

Keywords: Volatility Adjustment, Solvency II, Bonds, Insurance companies.

1 Introduction

In this paper we investigate the functioning of the Volatility Adjustment (VA) under different perspectives and we provide some hints on policy implications.

The Solvency II framework builds on market consistent evaluation of assets and liabilities of insurance companies. In order to cope with the volatility of the best estimate of liabilities (BEL), insurance companies are allowed to correct the discounting interest rate curve by the VA. The VA aims to translate into the risk free rate curve the component of the spread of bonds detained by insurance companies which is not associated with fundamentals and therefore is not due to the credit quality of bonds. Recital 32 of the Omnibus II Directive [10] states that *in order to prevent pro-cyclical investment behaviour, insurance and reinsurance undertakings should be allowed to adjust the relevant risk-free interest rate term structure for the calculation of the best estimate of technical provisions* *to mitigate the effect of exaggerations of bond spreads.* "Exaggerations of bond spreads" are interpreted as changes of bond prices that are not associated with default changes, and therefore they should refer mostly to market movements attributable to liquidity changes in the market. Thanks to the VA mechanism, the Own Funds of an insurance company should not be affected by non fundamental/temporary changes of bond prices: adding a portion of the spread observed in bond prices (risk corrected spread) to the liability discount rate, the anomalous market movements on the asset side should be by the BEL. The rationale is that being illiquid the liabilities, their evaluation should not incorporate temporary market movements.

This paper aims at investigating the VA as it is in force now and at analyzing some of the proposals that are under discussion.

The functioning of the VA has been challenging from many sides. In particular the following issues have been pointed out, see [7, 17, 25]:

- *Design of the VA*: the relationship between the assumptions underlying the VA and the goals pursued by the regulation is not made explicit and is not straightfoward. A drawback of this issue is the misestimation of risk correction of VA.
- *Basis risk*: there are significant differences between the reference portfolios adopted in computing the VA and the asset portfolio of insurance and reinsurance undertakings.
- *Over/undershoot*: due to choices by the insurance and reinsurance undertakings (e.g.asset allocation, credit quality), the impact of VA may over- or undershoot the impact of spread exaggerations on asset side.
- *Non symmetric*: VA almost always positive; not symmetric, i.e. no resilience build up in good times.
- *Illiquidity of liabilities*: the application of VA does not take into account illiquidity of liabilities.
- *Duration mismatch*: huge variance in the duration gaps between assets and liabilities of insurance companies depending on their business activities and asset portfolios.
- *Delay in the computation of weights*: in the time window considered in our analysis (2015-2019) there were only three updates in the portfolio weights used in computing the VA.

- *Cliff-edge effect*: the country specific component of the VA does not enter in a smooth way.
- *Non market consistency*: risk-free interest rates with VA not market-consistent.

The functioning of the VA is under scrutiny. In 2019, the European Parliament approved a change on the threshold for the country specific component of the VA (from 100 bps to 85 bps)[1]. Recently the European Commission asked EIOPA for a technical advice on the review of the Solvency II directive, see [16]: *EIOPA is asked to provide an assessment of the quantitative impact on the calculation of the best estimate and the solvency position of insurance undertakings of the following approaches for the calculation/application of the volatility adjustment:*

- *Approach 1: the application of an adjustment that takes into account the illiquidity features and/or duration of insurers' liabilities, while maintaining the current concept of representative portfolios. That adjustment may rely on different application ratios;*
- *Approach 2: the application of an adjustment that takes into account the weights of own assets holdings of each insurer; that adjustment may rely on different application ratios depending on the level of cash-flow matching of insurance liabilities portfolios. When applying this approach, EIOPA should specify the assumptions regarding diversification benefits in the calculation of the Solvency Capital Requirement.*

In addition, EIOPA is asked to review the functioning of the increased volatility adjustment per country given its purpose and suggest amendments to the measure where necessary.

EIOPA sent out a consultation document on the 15-th October 2019 with the goal of addressing these issues, see [17].

EIOPA identified the following main objectives that can be attributed to the VA:

1. Prevent procyclical investment behaviour;
2. Mitigate the impact of exaggerations of bond spreads on own funds;
3. Recognise illiquidity characteristics of liabilities in the valuation of technical provisions.

According to their analysis, some of these goals are not addressed by the mechanism in force.

[1] The new activation threshold will be in force by mid 2020.

In this paper we investigate the functioning of the VA addressing five different topics: cliff-edge effect, centrality of portfolio weights, determinants of the VA, effect of the VA on the Solvency II capital ratio and Asset& Liability implications. Our analysis shows the following main results:

- the VA doesn't capture country specific bond illiquidity features, it rather depends on risk appetite and uncertainty at the global level.
- The cliff-edge phenomenon is an issue with a significant variability on the activation of the country specific VA.
- The country specific VA is sensitive to the weights defined by EIOPA and to the hurdle (100 bps) for the activation.

We then concentrate on some policy options proposed in the EIOPA document to reform the VA.

The paper is organized as follows. In Section 2 we describe the functioning of the Volatility Adjustment. In Section 3 we provide a descriptive analysis on the evolution of the VA. In Section 4 we investigate how the VA has been affected by the change of portfolio weights for the computation of the VA. In Section 5 we investigate the determinants of the VA. In Section 6 we provide an empirical analysis on public information about the effect of the VA on Solvency ratio of insurance companies. An exercise on the effect of the VA on the present value of liabilities is presented in Section 7. In Section **??** we provide ana analysis of the policy options proposed by [17]. In Appendix A we outline the methodology that we have followed to compute the VA.

2 The functioning of the Volatility Adjustment

In what follows, we briefly describe how the VA works according to the regulation in force[2].

For each country, the VA is made up of two components: the currency VA (VA_{cu}) and the country VA (VA_{co}). The first component is defined as:

$$VA_{cu} = 65\% SRC_{cu},$$

[2] Article 77d of the Solvency II Directive specifies the calculation of the VA. This specification is further detailed the Delegated Regulation, specifically in Article 49-51.

where SRC_{cu} is the risk-corrected currency spread which is given by

$$SRC_{cu} = S_{cu} - RC_{cu},$$

where S_{cu} is the currency spread and RC_{cu} is the risk correction computed according to the reference portfolio associated with the currency and are defined as follows

$$\begin{aligned} S_{cu} &= w_{cu}^{gov} \max\{S_{cu}^{gov}, 0\} + w_{cu}^{corp} \max\{S_{cu}^{corp}, 0\}, & (1) \\ RC_{cu} &= w_{cu}^{gov} \max\{RC_{cu}^{gov}, 0\} + w_{cu}^{corp} \max\{RC_{cu}^{corp}, 0\}. & (2) \end{aligned}$$

We refer to Appendix A for the methodology to compute these components of the VA.

The VA_{co} is computed as:

$$VA_{co} = 65\% \max\{SRC_{co} - 2SRC_{cu}, 0\}. \tag{3}$$

where the risk-corrected country spread SRC_{co} is defined as in the currency case for a country specific reference portfolio.

Then, the VA is defined as

$$\text{VA} = 65\% \left(SRC_{cu} + \mathbf{1}_{SRC_{co} > 1\%} \max\{SRC_{co} - 2SRC_{cu}, 0\} \right).$$

Therefore, the VA is equal to VA_{cu} if $SRC_{co} \leq 1\%$ and $VA_{cu} + VA_{co}$ otherwise.

The variables at currency level are as follows:

- w_{cu}^{gov} denotes the weight of the value of government bonds included in the reference portfolio for that currency;
- w_{cu}^{corp} denotes the weight of the value of bonds other than government bonds, loans and securitisations included in the reference portfolio for that currency;
- S_{cu}^{gov} denotes the average spread of government bonds, loans and securitisations included in the reference portfolio for that currency;
- S_{cu}^{corp} denotes the average spread of bonds other than government bonds, loans and securitisations included in the reference portfolio for that currency;
- RC_{cu}^{gov} denotes the risk correction of government bonds included in the reference portfolio for that currency;

- RC_{cu}^{corp} denotes the risk correction of bonds other than government bonds, loans and securitisations included in the reference portfolio for that currency.

For example, the risk correction for corporate bonds is defined as:

$$RC_{cu}^{corp} = \max\{PD + CoD, 35\%LTAS\}$$

where:

- PD is the credit spread corresponding to the probability of default on the assets;
- CoD is the credit spread corresponding to the expected loss resulting from downgrading of the assets;
- $LTAS$ is the long-term (30 years) average of the spread over the risk-free interest rate of assets of the same duration, credit quality and asset class.

The risk correction RC_{cu}^{gov} is defined as $30\%LTAS$ for exposures to government and central banks of the Euro area, and as $35\%LTAS$ for other governments. We refer to Appendix A for details.

At country level, the country spreads ($S_{co}, S_{co}^{gov}, S_{co}^{corp}$), risk corrections ($RC_{co}, RC_{co}^{gov}, RC_{co}^{corp}$) and risk corrected spreads (SRC_{co}) are computed in a similar way with respect to a country reference portfolio which is representative of the assets detained by insurance and reinsurance companies to cover the BEL associated with products sold in the insurance market of that country and denominated in the currency of that country. We refer to Appendix A for details.

For a given currency, the VA is based on the spread between the interest rate associated with the bonds of a reference portfolio for that currency and the rates of the relevant basic risk-free interest rate term structure for that currency. The reference portfolio for a currency shall be representative for the bonds denominated in that currency that are detained by insurance and reinsurance to cover the BEL for insurance and reinsurance obligations denominated in that currency.

The VA corresponds to 65 % of the risk-corrected spread at currency level. The risk-corrected currency spread is calculated as the difference between the spread of the representative portfolio and the portion of that spread that is attributable to a realistic assessment of expected losses or unexpected credit or other risk of the assets detained by insurance companies. The risk correction is described in the Omnibus II Directive as *the portion of the spread that is attributable to a realistic assessment of expected losses, unexpected credit risk or any other risk, of the assets* in the reference portfolio.

The VA applies only to risk-free interest rates of the term structure that are not derived through the extrapolation technique. The VA can be applied to compute the BEL of products sold in the insurance market of that country. The VA shall not be applied with respect to insurance obligations where the relevant risk-free interest rate term structure to calculate the best estimate for those obligations includes a Matching Adjustment.

PD and CoD spreads are calculated by projecting credit downgrades and defaults over time using a transition matrix with fixed assumptions for the recovery rate of bonds on default, and scaling factors used to calculate the cost of downgrades. The transition matrix is based on data obtained from Standard & Poor's from 1987 onwards and is hence a long-term average that is updated annually.

3 A descriptive analysis

We reconstruct the VA of nineteen countries according to the methodology described in Section 2 and Appendix A. We deal with fourteen countries with Euro as currency: Austria (AT), Belgium (BE), Germany (DE), Finland (FI), France (FR), Greece (GR), Ireland (IE), Italy (IT), Netherlands (NL), Portugal (PT), Slovakia (SK), and Spain (ES).[3] We also consider some non EURO countries: more precisely we focus on Bulgaria (BG), Czech Republic (CZ), Hungaria (HU), Poland (PL), Sweeden (SE), and United Kingdom (UK). We have tested the validity of our methodology performing a backtesting on a monthly basis with respect to the data reported by EIOPA on a monthly basis.

The sample is made of monthly observations for the time span December 31, 2015, to April 30, 2019. Let us consider the VA, which is defined as

$$\text{VA} = VA_{cu} + VA_{co}\mathbf{1}_{SRC_{co}>0.01}.$$

There only two countries experiencing a VA $\neq VA_{cu}$ at the end of a month:

- **Greece**: 31/12/2015, 31/01/2016, 29/02/2016, 31/03/2016, 30/04/2016, 30/06/2016,

[3] We did not consider Cyprus, Estonia, Latvia, Lithuania, Malta, Slovenia for missing values on the bond market.

31/07/2016 and 31/08/2018.

- **Italy**: 31/08/2018, 31/10/2018 and 30/11/2018.

This observation suggests that the mechanism for the activation of the country specific component is quite selective.

In particular, the condition $SRC_{co} > 0.01$ for the activation of the VA_{co} is restrictive. To evaluate its relevance we consider two different thresholds. First, we assume that there is no constraint for the activation, thus we define

$$\mathrm{VA}_{mod} := VA_{cu} + VA_{co}.$$

Then the threshold is set at 85% as requested by the new regulation and we define VA_{85} as:

$$\mathrm{VA}_{85} := VA_{cu} + VA_{co}\mathbf{1}_{SRC_{co}>0.0085}.$$

In Table 1 we report the countries for which the VA_{co} is activated ($VA \neq VA_{cu}$) under the three different hypotheses: $\mathbf{1}_{SRC_{co}>0.01}$, $\mathbf{1}_{SRC_{co}>0.0085}$, $\mathbf{1}_{SRC_{co}>0}$. All the other countries that are not in Table 1 are such that $VA = VA_{cu}$ for all the months of the sample.

As expected, as the threshold increases the number of months/countries with activation of VA_{co} decreases. In particular, we have 116 month/country in which $\mathrm{VA}_{mod} \neq VA_{cu}$ (no threshold), 51 with a threshold at 85 bps and only 11 with a threshold at 100 bps.

This analysis highlights the magnitude of the cliff-edge issue and the relevance of the size of the threshold on the spread for the activation of the VA_{co}. Notice that the new threshold at 85 bps will render the VA much more dependent on the country specific VA.

Country	Without constraints on SRC_{co}	With constraint $SRC_{co} > 85$bps	With constraint $SRC_{co} > 100$bps
Bulgaria	16	-	-
Greece	26	19	8
Italy	30	9	3
Portugal	18	16	-
Spain	23	7	-
Sweeden	3	-	-

Table 1: Number of months with VA $\neq VA_{cu}$ with or without constraints on SRC_{co}.

We now analyze the time evolution of the different components of the VA.

In Figure 1 and 2, we plot the evolution of SRC_{cu} for the Euro and non Euro countries,

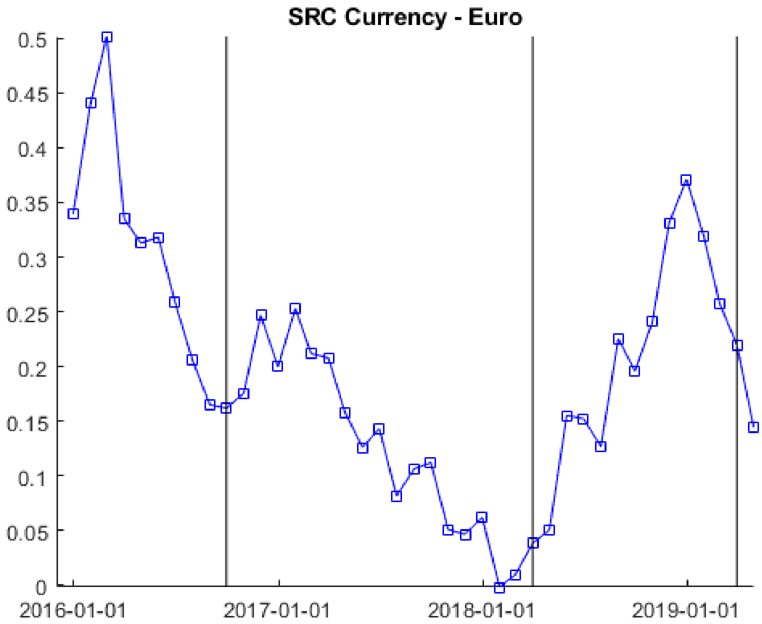

Figure 1: SRC_{cu} (in %) for the EURO countries

respectively.[4] Notice that dumped by the 65% ratio the SRC_{cu} coincides with the VA in case country specific components are not activated. Notice that the SRC_{cu} is almost always positive and therefore the instrument is not symmetric providing no resilience build up in "good times". We observe negative values for SRC_{cu} only for some eastern European countries (BG, HU and RO). A negative value for the SRC_{cu} may occur in case the risk correction is higher than the spread ($R_{cu} > S_{cu}$). Notice that this outcome should be interpreted as a distortion rather than an outcome with an economic rationale. The effect is due to the possibility that the spread be very low today as copared to the long-term average spread ($LTAS$).

Similarly, in Figure 3 (dividing countries between core and non-core countries) and 4 we plot the SRC_{co} for countries belonging to the euro-zone and not. Notice the significant values observed for Greece and Italy at the beginning and at the end of the sample, respectively.

In Figure 5 we plot the VA for countries that experience positive values for VA_{co} (for all the other countries, VA=$VA_{cu} = 0.65SRC_{cu}$). The time series show some jumps that display an oscillatory rather than decaying shape. The time serie is likely to be described

[4] In all figures, the vertical lines corresponds to date where EIPA changes the reference portfolio, see Section 4.

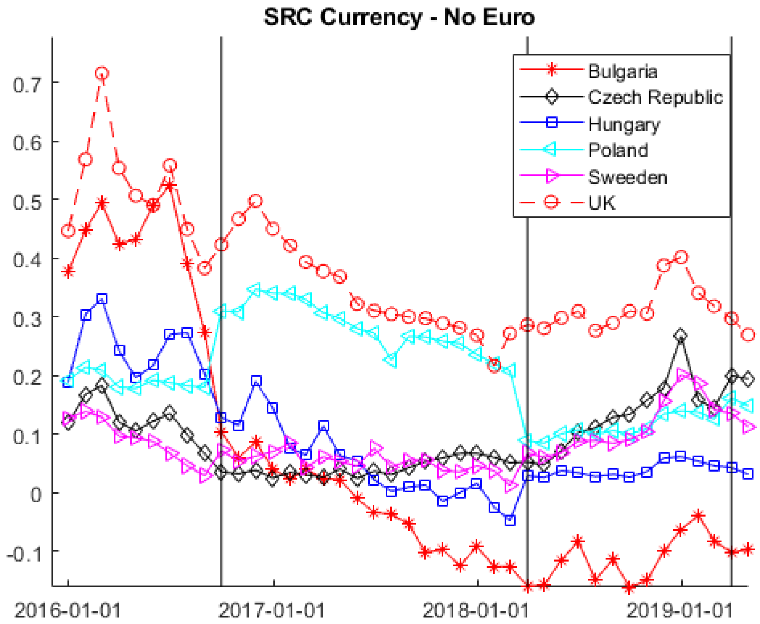

Figure 2: SRC_{cu} (in %) for non EURO countries

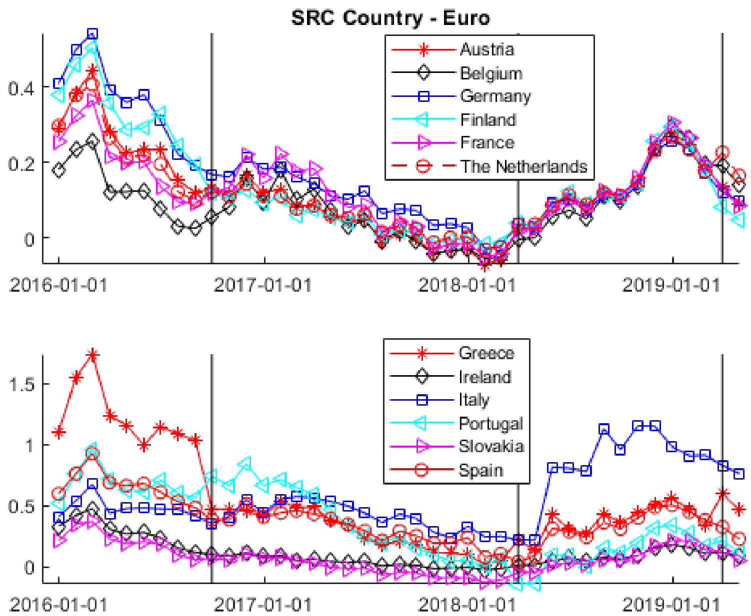

Figure 3: SRC_{co} (in %) for the EURO countries

by jump processes rather than autoregressive processes.

The cliff-edge phenomenon emerges explicitly. Notice that both in the Greece and Italy case the activation of the VA_{co} was not persistent, in the case of Greece during the crisis period five months of activation of the VA_{co} were followed by a month of non

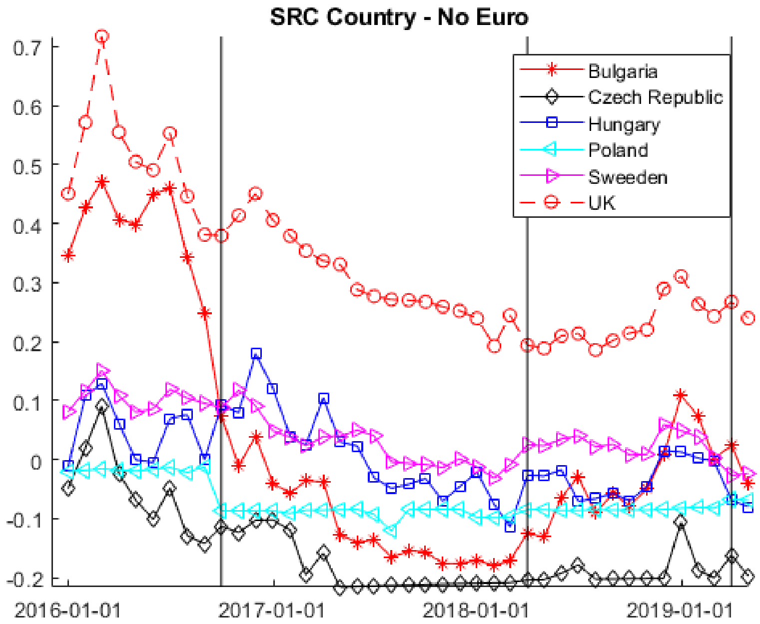

Figure 4: SRC_{co} (in %) for non EURO countries

activation and then other three months with activation. In 2018 the VA_{co} for Italy was activated in a month, then it was not in a month and then again it was activted for two months.,

The activation condition $SRC_{co} > 85$ bps shows a much more regular shape when the VA_{co}, see Figure 6. In this setting, a regime-shift model could be employed to model the evolution of the VA. Except for Italy, no evident differences appear in the dynamics of VA if we remove constraint on SRC_{co}, see Figure 7.

4 On Portfolios Weights

EIOPA changed the weights for computing the VA on three dates: September 30, 2016 (as communicated on July 1, 2016)[5], March 31, 2018 (as communicated on the December 18, 2017)[6], and March 31, 2019 (as communicated on December 18, 2018).[7]

One of the main criticism towards the VA for countries belonging to the Euro area is that the portfolio weights at currency level are not representative of portfolio weights at

[5] https://eiopa.europa.eu/Pages/News/EIOPA-updates-representative-portfolios-to-calculate-volatility-adjustments-to-the-Solvency-II-RFR-term-structures.aspx

[6] https://eiopa.europa.eu/Pages/News/EIOPA-updates-representative-portfolios-to-calculate-volatility-adjustments-to-the-Solvency-II-risk-free-interest-rate-term.aspx

[7] https://eiopa.europa.eu/Pages/News/EIOPA-updates-representative-portfolios-to-calculate-volatility.aspx

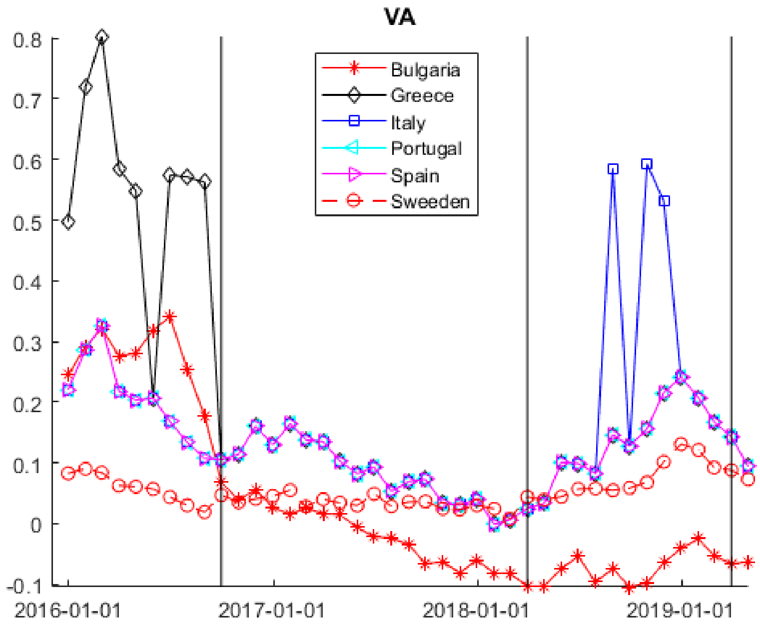

Figure 5: VA (in %) for the countries that display positive VA_{co} for specific or no restriction on SRC_{co}.

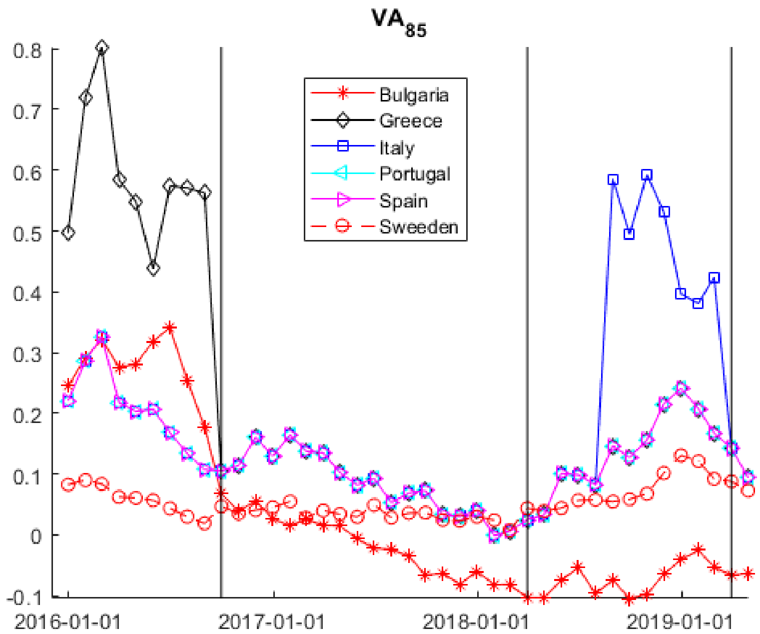

Figure 6: VA_{85} (in %) for the countries that display positive VA_{co} for specific or no restriction on SRC_{co}.

country level and this may favor insurance companies in some countries and may create a disadvantage to other companies. Moreover, there is a delay int eh definition of portfolio

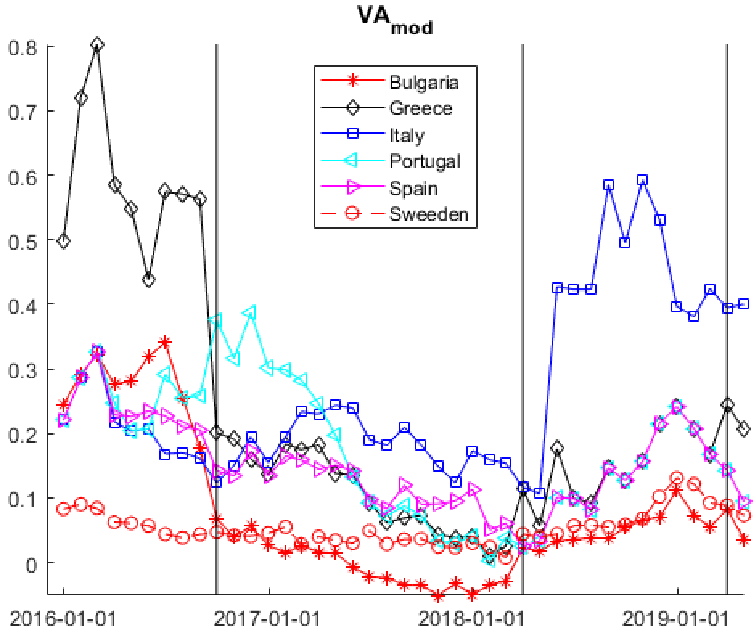

Figure 7: VA_{mod} (in %) for the countries that display positive VA_{co} for specific or no restriction on SRC_{co}.

weights and therefore they may not represent the true picture of investments by insurance companies.

To investigate this point we first consider a measure of the distance between portfolio weights at currency level and at country level. As a reference we consider the cosine similarity indicator. We restrict our attention to ten countries: Austria, Belgium, Germany, Spain, France, Greece, Ireland, Italy, The Netherlands, Portugal.

Let su briefly describe the indicator. Consider two N-dimensional vectors x and y. The cosine similarity of the two vectors is computed as:

$$\frac{\sum_{i=1}^{N} x_i \, y_i}{\sqrt{\sum_{i=1}^{N} x_i^2}\sqrt{\sum_{i=1}^{N} y_i^2}}. \tag{4}$$

The output of the cosine similarity index ranges in the interval $[-1, 1]$ where -1 stands for no similarity between the vectors while 1 is assigned in the case the two vectors coincide.

We compare the vectors of weights of the euro portfolio with the vectors of national weights. For each of the three periods with fixed weights (I, II, III), we consider the similarity indicator for the portfolio of government bonds, corporate bonds and the allocation between corporate and government bonds (two dimensional vector). For the last set of

	I	II	III
AT	0.415	0.463	0.513
BE	0.406	0.445	0.402
DE	0.570	0.554	0.631
ES	0.232	0.286	0.287
FR	0.834	0.772	0.802
GR	0.738	0.677	0.373
IE	0.550	0.762	0.784
IT	0.576	0.542	0.585
NL	0.413	0.548	0.544
PT	0.189	0.282	0.185

Table 2: Similarity of vectors containing the weights of investment in government bonds at the euro level and at country level.

weights we also report the difference in the weights for corporate bonds and government bonds. Results are reported in Tables 2, 3, 4, 5.

It is worthwhile to observe that the portfolio of government bonds concern the allocation among States, instead the portfolio of corporate bonds concerns the distinction between financial/non financial companies and the credit quality of bonds.

The degree of similarity is higher in case of portfolios of corporate bonds than in case of portfolios of government bonds. We can deduce that the heterogeneity among portfolios of government bonds of insurance companies belonging to different countries is quite high and instead that they hold similar portfolios of corporate bonds.

There is some evidence that insurance companies based in non core countries (ES, GR, IT, PT) detain portfolios that are quite different from the portfolio at euro level. In particular they detain portfolios of corporate bonds that are quite different from the portfolio at the Euro level.

The similarity indicator for the allocation between government bonds and corporate bonds is not very significant as the vectors are made up only of two components and their components do not sum up to 1, see Table 4. It is more interesting to have a look at the difference between the quota allocated to corporate bonds and that allocated to government bonds in different countries, see Table 5. From this Table we observe that at the euro level there is a positive difference with a larger quota of corporate bonds (+7.7%). As expected, instead insurance companies located in countries with a huge public debt detain a large quota invested in government bonds, instead insurance companies located in core countries tend to overweight corporate bonds.

	I	II	III
AT	0.950	0.923	0.929
BE	0.950	0.845	0.815
DE	0.947	0.608	0.612
ES	0.771	0.664	0.619
FR	0.959	0.923	0.881
GR	0.632	0.070	0.411
IE	0.904	0.733	0.780
IT	0.755	0.609	0.516
NL	0.873	0.884	0.885
PT	0.784	0.493	0.607

Table 3: Similarity of vectors containing the weights of investment in corporate bonds at the euro level and at country level.

	I	II	III
AT	0.997	0.983	0.985
BE	0.943	0.921	0.974
DE	0.936	0.960	0.976
ES	0.969	0.937	0.925
FR	1.000	0.999	0.992
GR	0.950	0.975	0.929
IE	1.000	1.000	0.991
IT	0.873	0.855	0.907
NL	1.000	0.995	0.999
PT	0.991	0.974	0.966

Table 4: Similarity of vectors containing the weights for investment in corporate bonds/government bonds at the euro and country level.

In what follows we plot the time series of VA and SCR_{co} assuming for the whole period (December 2015-April 2019) constant weights and durations for corporate and government bonds representative portfolios including the durations both at the currency and at the country level. For example, the blue line corresponds to the case where we assume that the weights and durations communicated on December 18, 2017 are used for the whole period (December 2015-April 2019), and not only from March 31, 2018 to February 28, 2019. The black line with squares mark the VA and SCR_{co} computed according to the weights and the durations that were in force at that time.

The analysis of the VA and of the SRC_{co} show that portfolio weights play a crucial role. In Figure 8 the VA and the SRC_{co} for AT, BE, FR, DE, NE, IE are plotted for the different sets of weights. As all the curves are close, the role of the representative

	I	II	III
Euro	0.095	0.164	0.077
AT	0.148	0.282	0.182
BE	-0.21	-0.145	-0.104
DE	0.461	0.396	0.237
ES	-0.124	-0.101	-0.226
FR	0.105	0.199	0.165
GR	-0.191	0.002	-0.208
IE	0.116	0.100	-0.019
IT	-0.369	-0.226	-0.256
NL	0.074	0.086	0.043
PT	-0.023	0.002	-0.123

Table 5: Difference for the weights for euro and national countries invested in corporate and government bonds.

portfolios seems negligible.

In Figure 9 we report the curves for GR, IT, ES, PT. It emerges that during period of crisis the reference portfolios' weights and durations play a relevant role. Considering the plot of Greece, Italy and Portugal we observe that there are months where the VA_{co} activation depends on the weights. For example, if we consider Greece, the change performed in 2016 results in a large decrease of the SRC_{co}, and thus of the VA. Considering the weights in force since March 2018, the VA_{co} would have been active for several months in 2016 and 2017. In the Italian case we observe a different phenomenon: considering the weights that were in force until August 2016, the VA_{co} would have been activated in 2018 for eight months instead of three as it happened with the actual months.

However, it is not possible to find a unique rationale under the behavior of the different curves. In fact, for Portugal the pink curve (2016-2018 weights) is the one with the largest SRC_{co} at the beginning of 2016, while for Greece the pink one is the one with the smallest SRC_{co}, in the same period. This can be explained by different portfolio allocations of insurance companies of the countries.

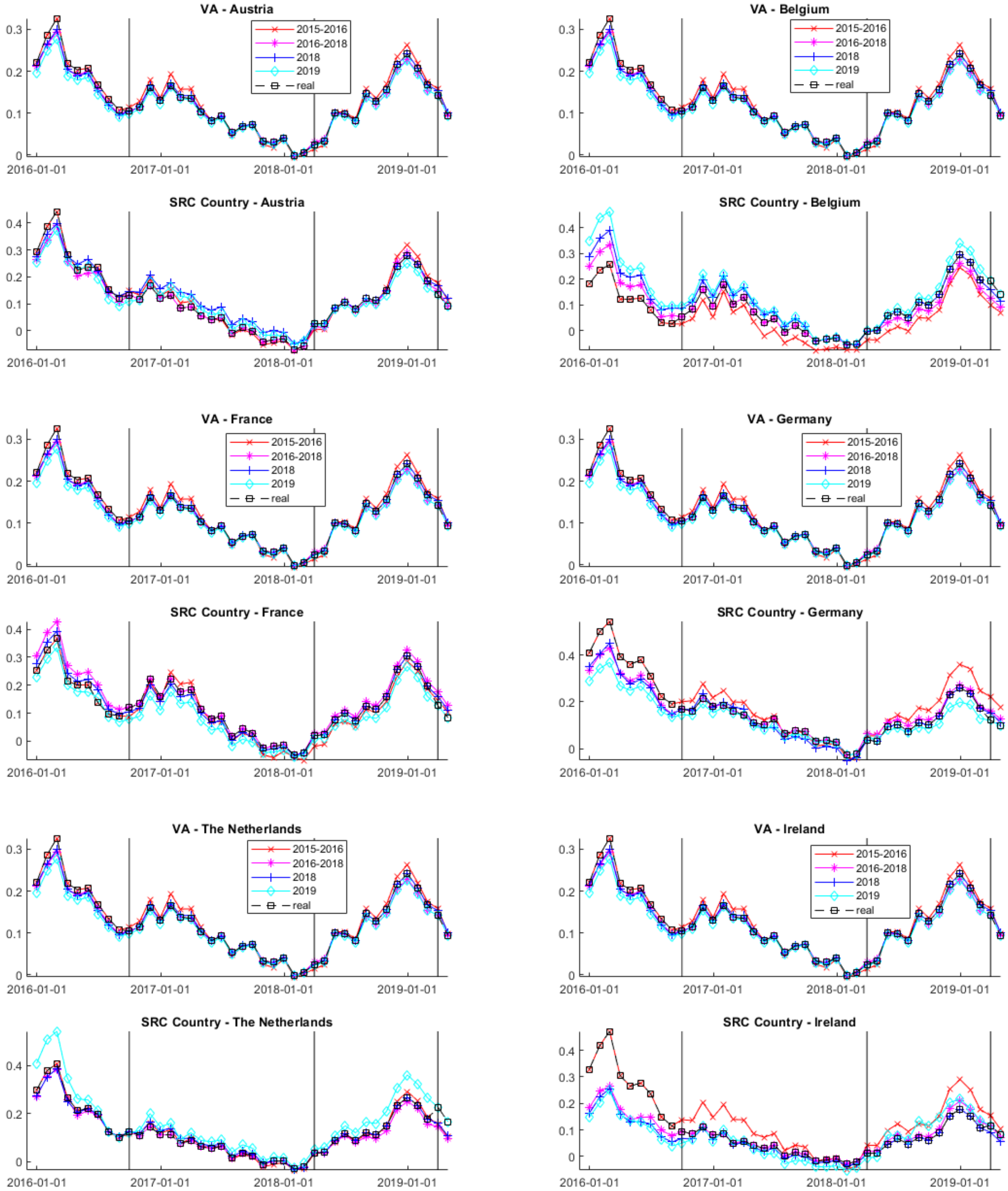

Figure 8: VA and SRC_{co} for AT, BE, FR, DE, NE, IR.

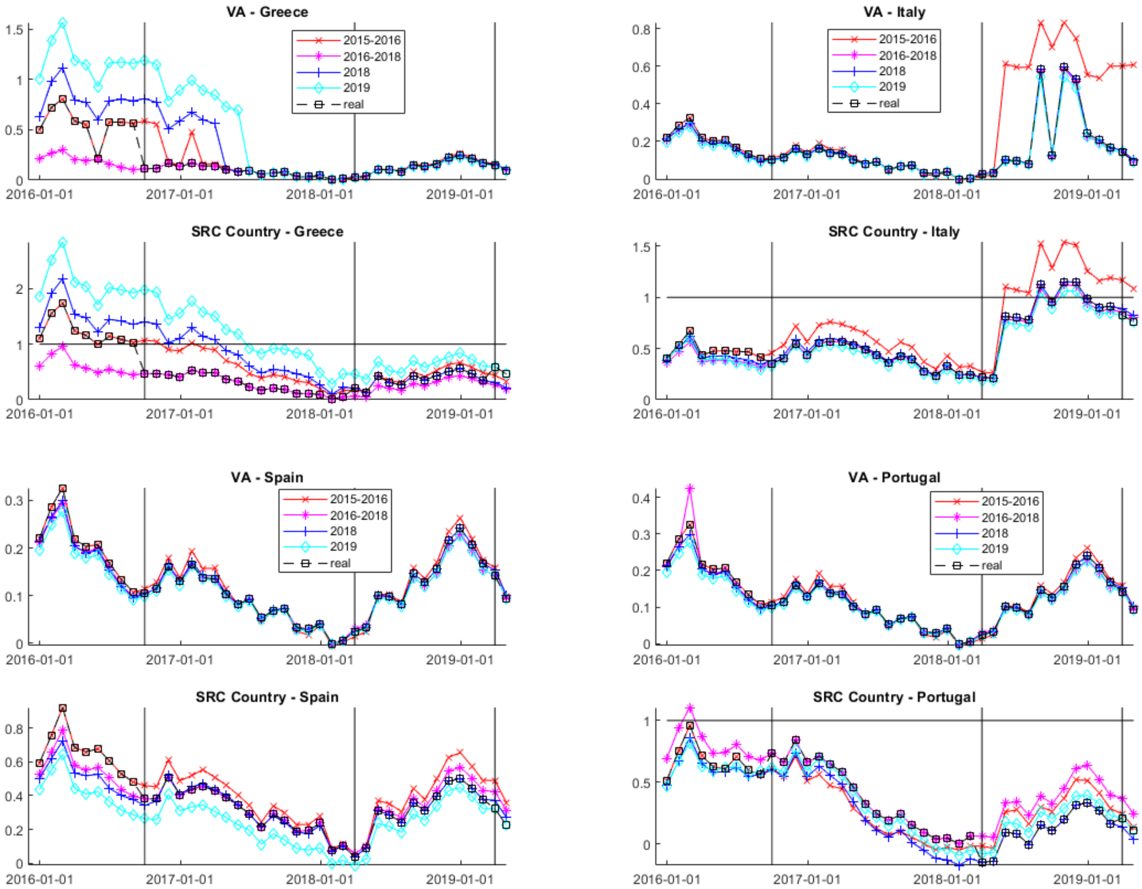

Figure 9: VA and SRC_{co} for GR, IT, ES, PT.

5 Determinants of the VA

According to the regulation, the VA should reflect components of the spread that are not related to the credit quality of the assets. This interpretation implies that the VA should mostly reflect exaggerations of the credit spread and the illiquidity of the bond markets.

In what follows we conduct a time series analysis to investigate whether the VA is effective in capturing exaggerations of bond spreads that are not associated with the credit quality of bonds. We concentrate our analysis on the VA with three different thresholds on the activation of VA_{co}: as it is now (VA), with a threshold at 85% (VA_{85}) and as it would be without a threshold (VA_{mod}). We look for determinants of the VA, we also analyze the SRC_{cu} and the SRC_{co}.

On a monthly basis we consider them as Y_t and we estimate the following autoregressive model for each country:

$$Y_t = \alpha + \beta_1 Y_{t-1} + \beta_2 X_t + \epsilon_t \tag{5}$$

where $\epsilon \sim N(0,1)$. X_t is a vector of exogenous variables that include both country specific factors and global factors. Both country specific and global factors were downloaded from Thompson Reuters. In particular, as country specific factors we consider:

- equity: equity index
- vol30: 30 days implied volatility of the equity market index
- yield 10y: yield of 10y government bonds
- yield10y_1y: the difference of 10 years and 1 year yield of government bonds
- cds5: the 5y credit default spread
- Bid_ask10y: the bid ask spread of 10y government bonds
- Ec_sent: indicator of economic sentiment.
- Target2: Total TARGET claims netted against total TARGET liabilities for a national central bank[8].

As global factors we include:

- VIX: implied volatility index
- BAA_AAA spread: yield difference of BAA and AAA rated bonds in the US market.

[8] The claims and liabilities of cross-border payments are known as TARGET balances. TARGET stands for "Trans-European Automated Real-time Gross Settlement Express Transfer System".

- Eurostoxx: 30 days historical volatility of the EUROSTOXX 50 Index.
- Iboxx: 30 days historical volatility of the the IBOXX Euro Corporates Index[9].

It is difficult to identify indicators of "exaggerations" in the bond markets.

The classical measure of illiquidity is provided by the bid-ask spread. Unfortunately, this measure i available only for government bonds markets (Bid_ask10y). Note that, there is evidence that this variable is positively associated to bond-yield spreads, see [3, 19, 18, 1, 8].

Looking for non fundamental factors that may affect the VA we consider the economic sentiment of the country (Ec_sent), see [20, 22]. This variable reflects fundamentals but also perceptions by people about the economic condition. In our analysis we have not included variables reflecting public finance fundamentals (public debt/GDP) and real economy performance (GDP, industrial production growth rate), or expectations on them, because they are not available on a monthly basis.

We capture the general investors' risk aversion on yield spreads by the difference between the yield of BAA corporate bonds and AAA corporate bonds in the United States (BAA_AAA spread), see [19, 18, 20].

As an indicator of uncertainty in financial markets we consider the VIX, which has been widely employed in the literature on the determinants of credit spreads of government bonds, see [1, 2, 8, 19, 21, 22, 4]. This variable provides a good proxy for turbulence in financial markets that may drive risk aversion in evaluating credit risk. Note that there is weak evidence that the VIX affects the VA before the euro crisis, instead the variable turns out to be statistically significant during and after the turbulent period. Results on Euro countries are presented in Tables 6,7 and 8. Tables 9,10 and 11 refer to non-Euro countries. The analysis provides several interesting insights.

First of all, we observe that with few exceptions (e.g. ES, GR, IT and PT) there is no significant looking at determinants of the VA depending on the activation threshold. So the proposed change to go from 100 bps to 85 bps would not change the main determinants of the VA.

The VA of all countries mostly depends on factors representing global risk appetite/perceived uncertainty (BAA_AAA, VIX). We observe only two countries where the VA is not

[9]The IBOXX Euro Corporates Index represents investment grade fixed-income bonds issued by public or private corporations.

influenced by global risk indices. The first is Italy, where we observe a positive dependence of VA_{85} and VA_{mod} only on *yield10y* and on cds5 while a negative dependence on the Ec_sent is observed for Portugal. The relevance of global risk indicators, and in particular of VIX, suggests that the VA mostly captures uncertainty and turbulence in financial markets.

There is very weak evidence in favor of the hypothesis that illiquidity of government bonds affects the VA. As a matter of fact, this variable is statistically significant at 5% only in Greece for the VA and VA_{85}. This result is confirmed by the analysis of the SRC_{co} which depends on the bid_ask spread of government bonds only in Slovakia. The same level of significance is found for the SRC_{cu} in Ireland.

Target2 imbalances may signal fly to quality phenomena and tensions in monetary/bond markets. It seems that this variable does not influence the VA. In particular, *Target2* is statistically significant at 5% only in France (VA, VA_{85} and VA_{mod}) and, for the VA_{mod}, in Portugal. The variable is statistically significant at 5% for SRC_{co} only for Sweden and for no countries referring to SRC_{cu}.

The level of the *yield10* rather than the difference *10y1y* seems to influence the dynamics of the VA especially in Germany, Spain, Ireland, Italy and Czech Republic. For the same countries it remains significant both for SRC_{co} and SRC_{cu} (except for SRC_{cu} in Italy).

The country riskiness in terms of *cds5* seems to be an important factor for all dependent variables in Spain, Greece, Italy, Portugal, Hungary, United Kingdom.

6 An analysis of the effect of the Volatility Adjustment

EIOPA provides an annual report on Long-term guarantees, see [12, 13, 14]. The 2016 report provide data for a limited set of markets. Therefore, in what follows we concentrate on the information available for 2017 and 2018 that refer to 2016 and 2017 balance sheet data. In 2018, 696 companies adopted the volatility adjustment (-34 with respect to 2017). Insurance and reinsurance companies using the VA represented 66% of the overall amount of technical provisions at the European Economic Area.

In Table 12 we report the effect of the VA on the SCR ratio in % pts in 20017 and 2018

	AT		BE		DE	
VA	VIX	5.14***e^{-04},-0.051**,83%	VIX	5.14***e^{-04},-0.051**,83%	VIX	5.14***e^{-04},-0.051**,83%
	BAA_AAA	0.12**,-0.057*,81%	BAA_AAA	0.12**,-0.057*,81%	BAA_AAA	0.12**,-0.057*,81%
			yield10y	0.047*,-0.021,79%	yield10y	-8.37***e^{-04},0.367***,82%
			equity	-3.57**e^{-04},0.129**,80%		
			vol30	0.294**,-0.013*,80%		
VA_{85}	-	-	-	-		
	-	-	-	-		
	-	-	-	-		
VA_{mod}	-	-	-	-		
	-	-	-	-		
	-	-	-	-		
SRC_{co}	VIX	0.069***,-0.106***,89%	VIX	0.007**,-0.038***,81%	VIX	0.007***,-0.084***,91%
	BAA_AAA	0.241***,-0.162***,87%	BAA_AAA	0.094*,-0.058,76%	BAA_AAA	0.138**,-0.086**,90%
	vol30	0.291**,-0.0327,85%	equity	-8.48**e^{-04},81%	yield10y	-0.001***,0.498***,90%
			Bid_ask10y	0.024*,0.007,76%		
SRC_{cu}	VIX	0.008***,-0.079**, 83%	VIX	0.008***,-0.079**, 83%	VIX	0.008***,-0.079**, 83%
	BAA_AAA	0.018**,-0.088*, 81%	BAA_AAA	0.180**,-0.088*, 81%	BAA_AAA	0.180**, -0.088*, 81%
			equity	-5.90**e^{-04},0.029**,80%	yield10y	-0.001***,0.564***,81%
			vol30	0.453**,-0.021, 80%		
			yield10	0.072*,-0.033, 79%		

Table 6: Results of fitting (5) respectively to VA, VA_{85}, VA_{mod}, SRC_{co} and SRC_{cu}. The first quantity refers to the coefficient β_2, the second to the intercept α and the last is the R^2. Significativity levels are denoted respectively with $*** < 0.01$, $** < 0.05$ and $* < 0.1$

	ES		FR	
VA	VIX	5.14***e^{-04},−0.051**,83%	VIX	5.14***e^{-04},−0.051**,83%
	BAA_AAA	0.12**,−0.057*,81%	BAA_AAA	0.12**,−0.057*,79%
	equity	-6.00***e^{-04},0.279***,82%2	Target2	3.53*** e^{-07},-0.002,82%
	yield10y	0.056**,0.056**,80%		
	cds5	9.81**e^{-04},-0.017,80%		
VA_{85}	-	-	-	-
	-	-	-	-
	-	-	-	-
VA_{mod}	VIX	3.68**e^{-03},−0.051**,76%	-	-
	BAA_AAA	0.12**,−0.057*,81%	-	-
	equity	-6.00e^{-04},0.303***,78%	-	-
	yield10y	0.069***,-0.086**,77%		
	yield10y1y	0.047*,-0.076,75%		
	cds5	0.002***,-0.018,73%		
	vol30	0.149*,0.012,75%		
	Eurostoxx	0.225**,0.009,76%		
SRC_{co}	VIX	0.009**,-0.091,82%	VIX	0.007***,-0.089***,82.7%
	BAA_AAA	0.211**,-0.092, 82%	BAA_AAA	0.105*,-0..059,77.5%
	yield10y	0.169***,0.216**,82%	Target2	-4.80*e^{-07},-8.30e^{-04}
	equity	-0.0015***,0.724***,83%		
	cds5	0.006***,-0.101***,89%		
	Target2	8.91*e^{-07},0.411**,81%		
	Eurostoxx	0.460*,0.012,81%		
SRC_{cu}	VIX	0.008***,-0.079, 83%	VIX	0.008***,-0.079, 83%
	BAA_AAA	0.180**,-0.089*, 81%	BAA_AAA	0.180**,-0.089*, 81%
	yield10y	0.086**,-0.106*,80%	Target2	-5.437*e^{-07},0.004, 79%
	equity	-9.23 e^{-04},0.430**,82%		
	cds5	0.002**,-0.027,80%		

Table 7: Results of fitting (5) respectively to VA, VA_{85}, VA_{mod}, SRC_{co} and SRC_{cu}. The first quantity refers to the coefficient β_2, the second to the intercept α and the last is the R^2. Significativity levels are denoted respectively with $*** < 0.01$, $** < 0.05$ and $* < 0.1$

for the whole market and for companies using the VA. The effect of the VA is significant: 96% of companies adopting the VA reported an absolute impact between 0 and 50%, 1%

		GR		IE		IT
VA	VIX	0.011**,-0.117,72%	VIX	5.14*** e^{-04},−0.051**,83%	VIX	0.011*,-0.069,30%
	BAA_AAA	0.354***,−0.113,75%	BAA_AAA	0.12**,−0.057*,81%	BAA_AAA	0.214*,−0.084*,29%
	yield10y1y	-0.046*,0.181*,71%	yield10y	0.061**,-0.044, 80%	yield10y	0.068**,-0.06,31%
	equity	0.008*,0.359*,72%	equity	-3.57** e^{-04}, 0.129**, 80%		
	vol30	0.609***,-0.0877***,85%				
	cds5	1.46*e^{-04},-0.030				
	Bid_ask10y	0.085**,-0.024,72.5%				
	Eurostoxx	1.437***,0.113***,82.7%				
VA_{85}	VIX	0.009**,-0.112*,83%	-	-	yield10y	0.064**,-0.094,69%
	BAA_AAA	0.265***,-0.183**,84%	-	-	cds5	0.001***,-0.145**,71%
	Eurostoxx	-0.046*,0.181*,71%	-	-		
	vol30	0.474***,-0.068***,88%				
	Bid_ask10y	0.055**,-0.018,82%				
	Eurostoxx	1.081***,-0.085***,87%				
VA_{mod}	VIX	0.009**,-0.117,84%	-	-	yield10y	0.095***,-0.093**,82%
	BAA_AAA	0.268***,-0.176**,85%	-	-	cds5	0.001***,-0.061,78%
	vol30	0.409***,-0.046**,84%				
	Eurostoxx	0.988***,-0.066**,87%				
SRC_{co}	VIX	0.019***,-0.227**,86%	VIX	0.006***,-0.079***,91%	yield10y	0.161***,-0.145**,82%
	BAA_AAA	0.524***,-0.0327**,86%	BAA_AAA	0.181**,-0.128***,91%	cds5	0.003***,-0.175**,82%
	vol30	0.720***,-0.056,88%	yield10y	0.064*,-0.055*,89%		
	Eurostoxx	1.579***,-0.082,86%	Bidask10y	0.123*,-0.017,89%		
			Ec_sent	0.004*,-0.439*,89%		
SRC_{cu}	VIX	0.008***,-0.079, 83%	VIX	0.008***,-0.079, 83%	VIX	0.008***,-0.079, 83%
	BAA_AAA	0.180**,-0.089*, 81%	BAA_AAA	0.180**,-0.089*, 81%	BAA_AAA	0.180**,-0.089*, 81%
	equity	-0.005**,0.243**,80%	yield10y	0.093**,-0.067,80%	equity	-1.06*e^{-05},0.260**, 80%
			Bidask10y	0.199**,-0.014,80%	cds5	8.90***e^{-04},-0.062*,81%

Table 8: Results of fitting (5) respectively to VA, VA_{85}, VA_{mod}, SRC_{co} and SRC_{cu}. The first quantity refers to the coefficient β_2, the second to the intercept α and the last is the R^2. Significativity levels are denoted respectively with $*** < 0.01$, $** < 0.05$ and $* < 0.1$

		NL		PT		SK
VA	VIX	0.005***,-0.051**,83%	VIX	0.005***,-0.051**,83%	VIX	0.005***,-0.051**,83%
	BAA_AAA	0.117**,−0.057,81%	BAA_AAA	0.117**,−0.057,81%	BAA_AAA	0.117**,−0.057,81%
	vol30	0.204*,-4.192,80%	equity	-0.001*,0.223*,79%	Bidask10y	0.042*,-0.016,79%
	Bidask10y	0.154*,0.029**,79%				
VA_{85}	-	-	-	-	-	-
	-	-	-	-	-	-
	-		-	-	-	-
VA_{mod}	-	-	VIX	0.005**,-0.052***,84%	-	-
	-	-	equity	-0.005***,0.576***,86%	-	-
	-	-	vol30	0.325**,-0.021,85%		
	-	-	cds5	3.20**e^{-04},0.003,841%		
	-	-	Ecsent	-0.008**,0.842**.84%		
	-	-	Target2	3.67**e^{-06},0.317**,84%		
	-	-	Eurostoxx	0.248**,-0.0125, 84%		
SRC_{co}	VIX	0.007***,-0.081***,89%	VIX	0.010**,-0.134*,86%	VIX	0.161***,-0.145**,82%
	BAA_AAA	0.282***,-0.178***,89%	BAA_AAA	0.186*,-0.134,86%	BAA_AAA	0.003***,-0.175**,82%
	vol30	0.248*,-0.009,84%	equity	-0.013**,1.613***,89%	Bidask10y	0.064**,-0.052*,86%
			vol30	0.877***,-0.081*,87%		
			cds5	0.002***,-0.067**,89%		
			Ec_sent	-0.023**,2.591**,87%		
			Target2	1.51*e^{-05},1.257***,89%		
			Eurostoxx	0.584**,-0.044,86%		
SRC_{cu}	VIX	0.008***,-0.079**, 83%	VIX	0.008***,-0.079**, 83%	VIX	0.008***,-0.079, 83%
	BAA_AAA	0.180**,-0.089*, 81%	BAA_AAA	0.180**,-0.089*, 81%	BAA_AAA	0.180**,-0.089*, 81%
	Bidask10y	-0.238*,0.045**,79.4%	equity	-0.0027*,0.343*, 79%	Bidask10y	0.0645*,-0.025, 79%

Table 9: Results of fitting (5) respectively to VA, VA_{85}, VA_{mod}, SRC_{co} and SRC_{cu}. The first quantity refers to the coefficient β_2, the second to the intercept α and the last is the R^2. Significativity levels are denoted respectively with $*** < 0.01$, $** < 0.05$ and $* < 0.1$

	BG		CZ		HU	
VA	VIX	0.003**,-0.056***,95%	VIX	0.003***,-0.025**,80%	VIX	0.003**,-0.034**,85%
	BAA_AAA	0.069**,−0.066**,95%	yield10y	0.009**,−0.003,78%	BAA_AAA	0.059**,−0.044**,86%
	Eurostoxx	0.223*,-0.035**,95%			equity	-4.82***e^{-06},0.189***,87%
					vol30	0.317***,-0.041***,87%
					cds5	0.001***,-0.125***,89%
VA_{85}	-	-	-	-	-	-
	-	-	-	-	-	-
	-		-	-	-	-
VA_{mod}	VIX	0.0046***,-0.063***,94%	-	-	-	-
	BAA_AAA	0.097**,-0.076**,93%	-	-	-	-
	Eurostoxx	0.274**,-0.029*,93%	-	-		
	Iboxx	5.463**,-0.158***,85%	-	-		
SRC_{co}	VIX	0.008***,-0.128***,95%	BAA_AAA	0.102**,-0.153***,76%	equity	-5.96e^{-06}***,0.206***,64%
	BAA_AAA	0.179***,-0.164***,94%	equity	-2.00*e^{-04},0.184,75%	vol30	0.405**,-0.059**,56%
	equity	6.74*e^{-04},0.402*,93%	vol30	0.520**,-0.120***,78%	cds5	0.001***,-0.133***,61%
	Eurostoxx	0.417**,-0.063**, 93%	cds5	0.008**,-0.388**,75%	Ecsent	-0.0062***,0.719***,58%
			Eurostoxx	0.298***,-0.102**,76%	Eurostoxx	0.275**,-0.039**,58%
SRC_{cu}	VIX	0.005**,0.086***, 95%	VIX	0.004***,-0.038**, 80%	VIX	0.004**,-0.0752**, 85%
	BAA_AAA	0.107**,-0.102*, 95%	yield10y	0.149**,-0.003**, 78%	BAA_AAA	0.091**,-0.067**, 86%
	Eurostoxx	0.344*,-0.054**,95%			equity	-7.41***e^{-06},-0.291***, 87%
					vol30	0.487***,-0.063***, 87%
					cds5	0.002***,-0.0194***, 85%
					Eurostoxx	0.433***,-0.037***, 88%

Table 10: Results of fitting (5) respectively to VA, VA_{85}, VA_{mod}, SRC_{co} and SRC_{cu}. The first quantity refers to the coefficient β_2, the second to the intercept α and the last is the R^2. Significativity levels are denoted respectively with $*** < 0.01$, $** < 0.05$ and $* < 0.1$

	PL		SE		UK	
VA	Ecsent	-0.002**,0.213**,85%	VIX	0.002***,-0.017*,78%	VIX	0.005***,-0.034,81%
					BAA_AAA	0.074**,−0.009**,79%
					equity	-7.82***e^{-05},0.685***,85%
					vol30	0.458***,0.002***,84%
					cds5	0.002**,0.004***,79%
					Eurostoxx	0.296***,0.031,88%
VA_{85}	-	-	VIX	0.002***,-0.017*,78%	-	-
	-	-	Bidask10y	-0.077*,0.022**,76%	-	-
	-	-			-	-
VA_{mod}	-	-	VIX	0.002***,-0.017*,78%	-	-
	-	-	-	-	-	-
	-		-	-	-	-
SRC_{co}	Eurostoxx	0.085**,-0.037***,80%	VIX	0.003***,-0.038***,82%	equity	-1.12**e^{-04},0.934***,93%
	BAA_AAA	0.029**,-0.047***,80%	equity	-1.60***e^{-04},0.258***,82%	vol30	0.651***,-0.012,87%
			vol30	0.192**,-0.019**,83%	cds5	0.003*,-0.022,85%
			Target2	-6.88**e^{-06},0.029**,81%	VIX	0.006**,-0.063*,86%
			Eurostoxx	0.206***,-0.019**,83%	BAA_AAA	0.104**,-0.041,87%
					Eurostoxx	0.417***, 0.013, 87%
SRC_{cu}	Ecsent	-0.003**,0.337**, 86%	VIX	0.003***,-0.025*, 78%	VIX	0.007***,-0.053, 81%
					BAA_AAA	0.113**,-0.013, 79%
					equity	-1.20***e^{-04},1.054, 85%
					vol30	0.705***,0.018, 84%
					cds5	0.004**,0.006, 79%

Table 11: Results of fitting (5) respectively to VA, VA_{85}, VA_{mod}, SRC_{co} and SRC_{cu}. The first quantity refers to the coefficient β_2, the second to the intercept α and the last is the R^2. Significativity levels are denoted respectively with $*** < 0.01$, $** < 0.05$ and $* < 0.1$

of companies using the measure reported an SCR ratio without the VA below 100% (8 companies representing 0.6% of technical provisions). Life and composite companies show in general slightly higher impacts on the SCR ratio than non-life companies.

	companies using the VA		market as a whole	
Country	2018	2017	2018	2017
EEA	17	24	9	13
AT	8	15	5	10
BE	18	27	17	15
BG	0	2	0	1
CY	1	8	0	0
CZ	5	7	2	2
DE	37	53	17	25
DK	41	80	26	58
ES	4	6	3	4
FI	1	6	1	4
FR	13	18	10	14
GR	4	9	2	7
HU	0	1	0	1
IE	3	7	0	0
IT	5	9	5	9
LI	1	12	1	0
LU	1	8	0	3
NL	42	49	31	39
NO	14	21	8	13
PT	2	7	1	3
RO	1	0	0	0
SE	5	3	0	0
SK	2	5	1	3
UK	3	6	1	2

Table 12: Absolute value of the difference between the SCR ratio with and without the VA: average value for companies adopting the VA and for all the market.

The data are significantly affected by companies adopting the Dynamic VA (DVA). In 2018, companies adopting an internal model and DVA have an average gain of 57% from using the DVA. Companies adopting the internal model and not the DVA have a gain of 6% from the VA. Finally, companies adopting the standard formula have a gain of 5% from the VA.

The reports by EIOPA also provide some information on the balance sheet of companies adopting the VA. Exploiting this information we constructed the following variables for the companies adopting the VA:

- Inv_{corp}: quota of assets invested in corporate bonds
- Inv_{gov}: quota of assets invested in Government bonds
- UL/IL: quota of assets invested in Unit/Index linked

- $Credit_{corp}$: quota of corporate bonds with a CQS$\geq$ 3 in a ranking between 0 and 6 (bonds between 0 and 3 are investment grade)
- $Credit_{gov}$: quota of government bonds with a CQS$\geq$ 3 in a ranking between 0 and 6 (bonds between 0 and 3 are investment grade)

We control for the level of the volatility adjustment (VA) of each country by the end of the year (2016 and 2017). Because of the limited size of the dataset (48 observations) we only consider two exogenous variables: the VA and one of the above variables. We estimate the following model:

$$y = \alpha + \beta VA + \gamma x + \epsilon$$

where x is provided by one of the variable outlined above. We run the regressions for the observations in 2018, 2017 (end of December in 2017 and 2016, respectively), for the full sample (full) and introducing a dummy variable d assuming a value equal to 1 in 2018 and 0 otherwise (dummy).

The sample is small and the statistical significance is weak, so we consider our analysis as an exercise with very high level policy implications. One main insight is derived from the analysis: companies investing in corporate/government bonds of low credit quality get a smaller gain from the VA. This result may be interpreted as showing that the architecture of the VA favors companies not taking excessive credit risk. There is also some weak evidence on the fact that the gain is limited in case of companies holding a large amount of unit/index linked in their portfolio.

7 A Liabilities experiment

The goal of this section is to highlight the role of the VA in discounting liabilities. Therefore we consider a (fixed) portfolio of liabilities of an insurance company discounting all its liabilities at the end of the year, exploiting the VA, the VA_{85}, the VA_{mod}, or with zero VA. This can be done exploiting historical data, and therefore dealing with the situation at December 31, 2015-2018.

Assume that we have to discount 1000 Euro to be paid in 2030. In Table 14 we report the discount value considering different choices to calculate VA, i.e., zero VA, VA=VA_{cu}, VA with two different thresholds (1%, the standard VA, and 0.85%, the VA_{85}), and the

x	data	coeff	s.e.	t_stat	p-value
Inv_{corp}	2018	-0.015	0.387	-0.039	0.969
	2017	0.249	0.497	0.500	0.623
	full	0.370	0.350	1.050	0.297
	dummy	0.105	0.322	0.325	0.746
Inv_{gov}	2018	0.004	0.209	0.018	0.986
	2017	-0.023	0.253	-0.089	0.929
	full	-0.246	0.169	-1.449	0.156
	dummy	-0.056	0.166	-0.337	0.738
UL/IL	2018	-0.212	0.132	-1.609	0.127
	2017	-0.248	0.175	-1.423	0.127
	full	-0.196	0.131	-1.499	0.143
	dummy	-0.209	0.113	-1.857	0.072
$Credit_{gov}$	2018	-0.067	0.092	-0.727	0.478
	2017	-0.108	0.120	-0.896	0.384
	full	-0.168	0.079	-2.118	0.041
	dummy	-0.092	0.077	-1.189	0.242
$Credit_{corp}$	2018	-0.283	0.232	-1.219	0.240
	2017	-0.262	0.226	-1.160	0.263
	full	-0.432	0.130	-3.315	0.002
	dummy	-0.251	0.164	-1.527	0.136

Table 13: Output of regression analysis with public data where the dependent variable is the effect on SCR ratio of companies using the VA.

	2015	2016	2017	2018
No VA	817.4218	880.6280	871.3862	896.6587
VA_{cu}	790.8242	864.7780	866.8297	871.0676
VA	790.8242	864.7780	866.8297	871.0676
VA_{85}	790.8242	864.7780	866.8297	855.0001
VA_{mod}	790.8242	861.7633	852.0023	855.0001

Table 14: Discount value of 1000 Euro in 2030, computed at December 31, 2015-2018.

VA_{mod}, where we recall that the VA is the sum of VA_{cu} and VA_{co}.

In the following, we assume that a national insurance company has to face liabilities having a discounted values (computing according to the EIOPA national risk-free curve - without VA) equal to 100 millions Euro. Our goal is to analyze the effect of VA at the end of each year. We assume the duration of the liabilities equal to the national one as provided in Figure 3 of the International Monetary Fund Report of July 2018, [10] reported

[10]https://www.imf.org/en/Publications/CR/Issues/2018/07/19/Euro-Area-Policies-Financial-Sector-Assessment-Program-Technical-Note-Insurance-Investment-46104

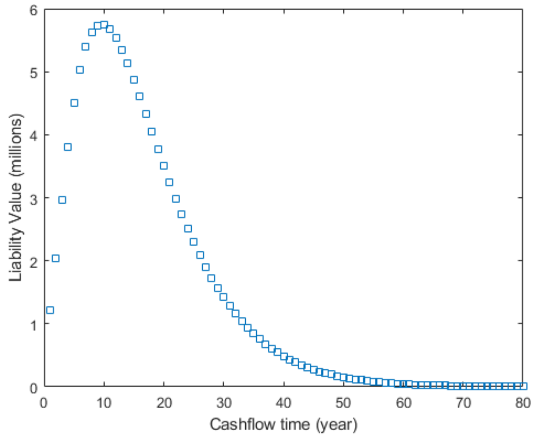

Figure 10: Liabilities values for France: discounted value equal to 100 millions, duration equal to 14.

AT	BE	DE	ES	FR	GR	IE	IT	NL	PT
16	11	22	10	13	10	11	9	17	5

Table 15: Durations.

in Table 15, and we simulate the liabilities accordingly (see Figure 10).

In Table 16 we study the effect of VA -for different national insurance companies belonging to countries where $VA_{co} \neq 0$- in discounting liabilities at the end of each year. We also consider a change in the duration τ in Table 15, adding and subtracting the value 2. Similarly, in Table 17 we consider other Euro members, having $VA_{co} = 0$, i.e., they have the same VA which is the Euro VA_{cu}. Table 18 contains a recap of the advantage of exploiting the VA in discounting liabilities.

Finally, in Tables 19-20 we perform the same analysis, recomputing the VA modifying the weigths w_{cu}^{gov} and w_{cu}^{corp} in Equations (1)-(2). More precisely, we increase (decrease) the weights of a factor 1.2 (0.8) to study how the VA (and therefore the discounted value of the liabilities) changes. Notice that these are the currency weigths, therefore we are considering the same weights for all the countries, i.e., the Euro weights. However, we notice that a change in these weigths produces different effects on the VA, and therefore on the discounting procedure: for example, if we consider the classical VA, decreasing the w_{cu}^{gov} usually results in an increase or the discounted value of the liabilities, with the exception of the case of Greece in December 31, 2015. Notice that in this case the Greece SRC_{co} was larger than 100 bps, and therefore VA$\neq VA_{cu}$. This effect is more evident

	ES		GR		IT		PT	
Duration	VA	VA_{mod}	VA	VA_{mod}	VA	VA_{mod}	VA	VA_{mod}
	December 31, 2015							
$\tau - 2$	98.2680	98.2680	96.1527	96.1527	98.4777	98.4777	99.3417	99.3417
τ	97.8670	97.8670	95.2758	95.2758	98.0640	98.0640	98.9065	98.9065
$\tau + 2$	97.4934	97.4934	94.4612	94.4612	97.6761	97.6761	98.4777	98.4777
	December 31, 2016							
$\tau - 2$	98.9761	98.9413	98.9761	98.9223	99.1005	98.9289	99.6119	99.1017
τ	98.7375	98.6947	98.7375	98.6713	98.8548	98.6366	99.3546	98.5096
$\tau + 2$	98.5151	98.4647	98.5151	98.4373	98.6242	98.3626	99.1005	97.9276
	December 31, 2017							
$\tau - 2$	99.6803	99.1059	99.6803	99.6803	99.7193	98.8033	99.8791	99.8791
τ	99.6056	98.8978	99.6056	99.6056	99.6423	98.4777	99.7987	99.7987
$\tau + 2$	99.5358	98.7036	99.5358	99.5358	99.5700	98.1724	99.7193	99.7193
	December 31, 2018							
$\tau - 2$	98.1073	98.1073	98.1073	98.1073	98.3363*	97.2873	99.2800	99.2800
τ	97.6693	97.6693	97.6693	97.6693	97.8845*	96.5567	98.8045	98.8045
$\tau + 2$	97.2618	97.2618	97.2618	97.2618	97.4611*	95.8740	98.3363	98.3363

Table 16: Discounted values of the liabilities (in millions) exploiting VA and VA_{mod}. τ is the duration reported in Table 15. VA_{85} is always equal to the classical VA, with the exception of the * cases, in which it equals the VA_{mod}.

Duration	AT	BE	IE	DE	FR	NL
	December 31, 2015					
$\tau - 2$	97.1538	98.0640	98.0640	96.3458	97.4934	97.0006
τ	96.8530	97.6761	97.6761	96.1354	97.1538	96.7142
$\tau + 2$	96.5836	97.3195	97.3195	95.9526	96.8530	96.4614
	December 31, 2016					
$\tau - 2$	98.3126	98.8548	98.8548	97.8303	98.5151	98.2199
τ	98.1333	98.6242	98.6242	97.7050	98.3126	98.0499
$\tau + 2$	97.9720	98.4107	98.4107	97.5979	98.1333	97.8991
	December 31, 2017					
$\tau - 2$	99.4724	99.6423	99.6423	99.3201	99.5358	99.4435
τ	99.4160	99.5700	99.5700	99.2810	99.4724	99.3899
$\tau + 2$	99.3653	99.5032	99.5032	99.2466	99.4160	99.3424
	December 31, 2018					
$\tau - 2$	96.8909	97.8845	97.8845	96.0086	97.2618	96.7220
τ	96.5602	97.4611	97.4611	95.7771	96.8909	96.4108
$\tau + 2$	96.2686	97.0712	97.0712	95.5835	96.5602	96.1352

Table 17: Discounted values of the liabilities (in millions) exploiting VA. τ is the duration reported in Table 15.

ES	GR	IT	PT	AT
December 31, 2015				
2.1330	4.7242	1.9360	1.0935	3.1470
December 31, 2016				
1.2625	1.2625	1.1452	0.6454	1.8667
December 31, 2017				
0.3944	0.3944	0.3577	0.2013	0.5840
December 31, 2018				
2.3307	2.3307	2.1155	1.1955	3.4398

BE	IE	DE	FR	NL
December 31, 2015				
2.3239	2.3239	3.8646	2.8462	3.2858
December 31, 2016				
1.3758	1.3758	2.2950	1.6874	1.9501
December 31, 2017				
0.4300	0.4300	0.7190	0.5276	0.6101
December 31, 2018				
2.5389	2.5389	4.2229	3.1091	3.5892

Table 18: Advantage of exploiting the VA in the discounted values of the liabilities (in millions). Difference between the discounted values exploiting only the risk-free curve and the one obtained exploiting also the VA.

when we consider the VA_{mod} in Table 19: decreasing the w_{cu}^{gov} could result in both an increase or a decrease of the discounted value of the liabilities.

	ES		GR		IT		PT	
Weights	VA	VA_{mod}	VA	VA_{mod}	VA	VA_{mod}	VA	VA_{mod}
	December 31, 2015							
$(w_{cu}^{gov}, w_{cu}^{corp})$	97.8670	97.8670	95.2758	95.2758	98.0640	98.0640	98.9065	98.9065
$(0.8w_{cu}^{gov}, w_{cu}^{corp})$	97.9535	97.9535	95.1924	95.1924	98.1426	98.1426	98.9511	98.9511
$(1.2w_{cu}^{gov}, w_{cu}^{corp})$	97.7806	97.7806	95.3592	95.3592	97.9855	97.9855	98.8619	98.8619
$(w_{cu}^{gov}, 0.8w_{cu}^{corp})$	98.2017	98.0473	94.9545	94.9545	98.3681	98.3681	99.0790	99.0790
$(w_{cu}^{gov}, 1.2w_{cu}^{corp})$	97.5338	97.5338	95.5985	95.5985	97.7612	97.76126	98.7343	98.7343
$(0.8w_{cu}^{gov}, 1.2w_{cu}^{corp})$	97.6199	97.6199	95.5148	95.5148	97.8395	97.8395	98.7789	98.7789
$(1.2w_{cu}^{gov}, 0.8w_{cu}^{corp})$	98.1149	98.1149	95.0375	95.0375	98.2892	98.2892	99.0343	99.0343
	December 31, 2016							
$(w_{cu}^{gov}, w_{cu}^{corp})$	98.7375	98.6947	98.7375	98.6713	98.8548	98.6366	99.3546	98.5096
$(0.8w_{cu}^{gov}, w_{cu}^{corp})$	98.8089	98.6235	98.8089	98.6001	98.9195	98.5722	99.3912	98.4735
$(1.2w_{cu}^{gov}, w_{cu}^{corp})$	98.6663	98.6663	98.6663	98.6663	98.7901	98.7012	99.3180	98.5458
$(w_{cu}^{gov}, 0.8w_{cu}^{corp})$	98.9168	98.5160	98.9168	98.4926	99.0175	98.4748	99.4466	98.4189
$(w_{cu}^{gov}, 1.2w_{cu}^{corp})$	98.5587	98.5587	98.5587	98.5587	98.6924	98.6924	99.2628	98.6004
$(0.8w_{cu}^{gov}, 1.2w_{cu}^{corp})$	98.6299	98.6299	98.6299	98.6299	98.7570	98.7342	99.2993	98.5643
$(1.2w_{cu}^{gov}, 0.8w_{cu}^{corp})$	98.8454	98.5871	98.8454	98.5637	98.9526	98.5392	99.4099	98.4550
	December 31, 2017							
$(w_{cu}^{gov}, w_{cu}^{corp})$	99.6056	98.8978	99.6056	99.6056	99.6423	98.4777	99.7987	99.7987
$(0.8w_{cu}^{gov}, w_{cu}^{corp})$	99.6692	98.8349	99.6692	99.6692	99.7000	98.4210	99.8312	99.8312
$(1.2w_{cu}^{gov}, w_{cu}^{corp})$	99.5421	98.9608	99.5421	99.5421	99.5847	98.5345	99.7662	99.7662
$(w_{cu}^{gov}, 0.8w_{cu}^{corp})$	99.6207	98.8829	99.6207	99.6207	99.6560	98.4642	99.8064	99.8064
$(w_{cu}^{gov}, 1.2w_{cu}^{corp})$	99.5905	98.9128	97.9987	97.9987	99.6287	98.4911	99.7910	99.7910
$(0.8w_{cu}^{gov}, 1.2w_{cu}^{corp})$	99.6541	98.8498	99.6541	99.6541	99.6864	98.4344	99.8235	99.8235
$(1.2w_{cu}^{gov}, 0.8w_{cu}^{corp})$	99.5571	98.9459	99.5571	99.5571	99.5983	98.5210	99.7739	99.7739
	December 31, 2018							
$(w_{cu}^{gov}, w_{cu}^{corp})$	97.6693	97.6693	97.6693	97.6693	97.8845*	96.5567	98.8045	98.8045
$(0.8w_{cu}^{gov}, w_{cu}^{corp})$	97.7996	97.7996	97.7996	97.7996	98.0028*	96.4408	98.8717	98.8717
$(1.2w_{cu}^{gov}, w_{cu}^{corp})$	97.5393	97.5393	97.5393	97.5393	97.7663*	96.6729	98.7373	98.7373
$(w_{cu}^{gov}, 0.8w_{cu}^{corp})$	97.9987	97.9987	99.5905	99.5905	98.1837*	96.2643	98.9745	98.9745
$(w_{cu}^{gov}, 1.2w_{cu}^{corp})$	97.3415	97.3415	97.3415	97.3415	97.5865*	96.8504	98.6349	98.6349
$(0.8w_{cu}^{gov}, 1.2w_{cu}^{corp})$	97.4711	97.4711	97.4711	97.4711	97.7043*	96.7340	98.7020	98.7020
$(1.2w_{cu}^{gov}, 0.8w_{cu}^{corp})$	97.8681	97.8681	97.8681	97.8681	98.0651 *	96.3800	98.9071	98.9071

Table 19: Discounted values of the liabilities (in millions) exploiting VA and VA_{mod}. w_{cu}^{gov} and w_{cu}^{corp} are to the EIOPA reference values. VA_{85} is always equal to the classical VA, with the exception of the * cases, in which it equals the VA_{mod}.

Weights	AT	BE	IE	DE	FR	NL
	December 31, 2015					
$(w_{cu}^{gov}, w_{cu}^{corp})$	96.8530	97.6761	97.6761	96.1354	97.1538	96.7142
$(0.8w_{cu}^{gov}, w_{cu}^{corp})$	96.9800	97.7702	97.7702	96.2909	97.2688	96.8467
$(1.2w_{cu}^{gov}, w_{cu}^{corp})$	96.7262	97.5820	97.5820	95.9802	97.0390	96.5819
$(w_{cu}^{gov}, 0.8w_{cu}^{corp})$	97.3447	98.0404	98.0404	96.7377	97.5990	97.2273
$(w_{cu}^{gov}, 1.2w_{cu}^{corp})$	96.3644	97.3135	97.3135	95.5374	96.7112	96.2044
$(0.8w_{cu}^{gov}, 1.2w_{cu}^{corp})$	96.4906	97.4072	97.4072	95.6918	96.8255	96.3360
$(1.2w_{cu}^{gov}, 0.8w_{cu}^{corp})$	97.2171	97.9459	97.9459	96.5814	97.4835	97.0941
	December 31, 2016					
$(w_{cu}^{gov}, w_{cu}^{corp})$	98.1333	98.6242	98.6242	97.7050	98.3126	98.0499
$(0.8w_{cu}^{gov}, w_{cu}^{corp})$	98.2385	98.7019	98.7019	97.8340	98.4077	98.1597
$(1.2w_{cu}^{gov}, w_{cu}^{corp})$	98.0283	98.5467	98.5467	97.5761	98.2176	97.9402
$(w_{cu}^{gov}, 0.8w_{cu}^{corp})$	98.3977	98.8195	98.8195	98.0295	98.5517	98.3260
$(w_{cu}^{gov}, 1.2w_{cu}^{corp})$	97.8698	98.4295	98.4295	97.3816	98.0742	97.7747
$(0.8w_{cu}^{gov}, 1.2w_{cu}^{corp})$	97.9746	98.5070	98.5070	97.5102	98.1690	97.8842
$(1.2w_{cu}^{gov}, 0.8w_{cu}^{corp})$	98.2923	98.7417	98.7417	97.9001	98.4564	98.2159
	December 31, 2017					
$(w_{cu}^{gov}, w_{cu}^{corp})$	99.4160	99.5700	99.5700	99.2810	99.4724	99.3899
$(0.8w_{cu}^{gov}, w_{cu}^{corp})$	99.5101	99.6394	99.6394	99.3968	99.5575	99.4882
$(1.2w_{cu}^{gov}, w_{cu}^{corp})$	99.3219	99.5008	99.5008	99.1653	99.3875	99.2916
$(w_{cu}^{gov}, 0.8w_{cu}^{corp})$	99.4383	99.5865	99.5865	99.3084	99.4926	99.4132
$(w_{cu}^{gov}, 1.2w_{cu}^{corp})$	99.3937	99.5536	99.5536	99.2535	99.4523	99.3666
$(0.8w_{cu}^{gov}, 1.2w_{cu}^{corp})$	99.4878	99.6229	99.6229	99.3693	99.5373	99.4649
$(1.2w_{cu}^{gov}, 0.8w_{cu}^{corp})$	99.3442	99.5172	99.5172	99.1927	99.4076	99.3149
	December 31, 2018					
$(w_{cu}^{gov}, w_{cu}^{corp})$	96.5602	97.4611	97.4611	95.7771	96.8909	96.4108
$(0.8w_{cu}^{gov}, w_{cu}^{corp})$	96.7514	97.6028	97.6028	96.0111	97.0639	96.6102
$(1.2w_{cu}^{gov}, w_{cu}^{corp})$	96.3695	97.3196	97.3196	95.5438	96.7182	96.2120
$(w_{cu}^{gov}, 0.8w_{cu}^{corp})$	97.0439	97.8195	97.8195	96.3693	97.3287	96.9153
$(w_{cu}^{gov}, 1.2w_{cu}^{corp})$	96.0794	97.1044	97.1044	95.1891	96.4555	95.9096
$(0.8w_{cu}^{gov}, 1.2w_{cu}^{corp})$	96.2694	97.2454	97.2454	95.4215	96.6276	96.1077
$(1.2w_{cu}^{gov}, 0.8w_{cu}^{corp})$	96.8520	97.6774	97.6774	96.1343	97.1550	96.7151

Table 20: Discounted values of the liabilities (in millions) exploiting VA. w_{cu}^{gov} and w_{cu}^{corp} are to the EIOPA reference values.

References

[1] Antonio Afonso, Arghyrou, Michael G., and Kontonikas, Alexandros (2015) The determinants of sovereign bond yield spreads in the EMU, European Central bank, working paper nr. 1781.

[2] Arghyrou, Michael G. and Kontonikas, Alexandros (2012) The EMU sovereign-debt crisis: Fundamentals, expectations and contagion, *Journal of International Financial Markets, Institutions & Money*, 22: 658-677.

[3] Beber, A., Brandt, M., Kavajecz, K., (2009) Flight-to-quality or flight-to-liquidity? Evidence from the euro-area bond market, *Review of Financial Studies*, 22, 925-957.

[4] John Beirne and Marcel Fratzscher (2013) The pricing of sovereign risk and contagion during the european sovereign debt crisis, *Journal of International Money and Finance*, 34: 60-82.

[5] Hans Blommestein, Sylvester Eijffinger, and Zongxin Qian (2016) Regime-dependent determinants of Euro area sovereign CDS spreads, *Journal of Financial Stability*, 22: 10-21.

[6] Carmen Broto and Gabriel Perez-Quiros (2015) Dinsetangling contagion among sovereign CDS spreads during the european debt crisis, *Journal of Empirical Finance*, 32: 165-179.

[7] Deloitte (2018) Volatility adjustment under the loop.

[8] De Santis, R.A. (2012) The Euro Area Sovereign Debt Crisis: Safe Haven, Credit Rating Agencies and the Spread of the Fever from Greece, Ireland and Portugal, *ECB Working Paper*, No. 1419.

[9] European Commission (2019) Request to EIOPA for technical advice on the review of the Solvency II directive, Directive 2009/138/EC.

[10] European Parliament (2014) Directive 2014/51/EU.

[11] European Insurance and Occupational Pensions Authority (2015) Technical documentation of the methodology to derive EIOPA's risk-free interest rate term structures.

[12] European Insurance and Occupational Pensions Authority (2016) Report on long-term guarantees measures and measures of equity risk 2016.

[13] European Insurance and Occupational Pensions Authority (2017) Report on long-term guarantees measures and measures of equity risk 2017.

[14] European Insurance and Occupational Pensions Authority (2018) Report on long-term guarantees measures and measures of equity risk 2018.

[15] European Insurance and Occupational Pensions Authority (2018) Technical documentation of the methodology to derive EIOPA's risk-free interest rate term structures.

[16] European Insurance and Occupational Pensions Authority (2019) Request to EIOPA for technical advice on the review of the Solvency II directive.

[17] European Insurance and Occupational Pensions Authority (2019b) Consultation paper on the Opinion on the 2020 review of Solvency II.

[18] Favero, C.A.(2013) Modelling and forecasting government bond spreads in the euro area: a GVAR model, *Journal of Econometrics*, 177: 343-356.

[19] Favero, C.A., Pagano, M., von Thadden, E.-L. (2010) How does liquidity affect government bond yields?, *Journal of Financial and Quantitative Analysis* 45, 107?134.

[20] Georgoutsos, Dimitris A. and Migiakis, Petros M. (2013) Heterogeneity of the determinants of euro-area sovereign bond spreads; what does it tell us about financial stability? *Journal of Banking & Finance*, 37: 4650-4664.

[21] Gerlach, S., Schulz, A., Wolff, G.B., 2010. Banking and sovereign risk in the euro area. CEPR Discussion Paper, N. 7833.

[22] Marta Gomez-Puig, Simon Sosvilla-Rivero, Maria del Carmen Ramos-Herrera (2014) An update on EMU sovereign yield spread drivers in times of crisis: A panel data analysis, *North American Journal of Economics and Finance*, 30: 133?153.

[23] Peter Løchte Jørgensen (2018) An analysis of the Solvency II regulatory framework's Smith-Wilson model for the term structure of risk-free interest rates, *Journal of Banking and Finance*, 97: 219?237.

[24] Alain Monfort and Jean-Paul Renne Decomposing euro-area sovereign spreads: credit and liquidity risks.

[25] Karl Murray and Eamonn Phelan (2019) Solvency II under review, Milliman.

[26] Van den As, D. (2015). Solvency II's Volatility Adjustment in Volatile Times.

A The computation of the Volatility Adjustment

The computation of the VA is deeply related to the computations of Internal Rate of Returns (IRR). In fact it holds

$$\begin{aligned} S &= IRR1 - IRR2 \\ RC &= IRR1 - IRR3, \end{aligned}$$

for both country and currency, gov and corp, even if some differences occurs. In this appendix we will sketch how the IRRs are computed considering as an example a country in the Euro area. For further details, we refer to the EIOPA documentation.

A.1 Country/Currency - Gov

EIOPA provides the composition of the representative portfolio of central government and central banks bonds for each country/for the currency Euro, as well as the corresponding durations. Given a country/the currency Euro, for each bond issuers belonging to its reference portfolio:

- we construct the market interest rate curve, according to the EIOPA documentation (for example, if the bond issuer is Italy, we consider the zero coupon rates), interpolating the curve in the corresponding duration and therefore obtaining the market yield before risk correction;
- we consider the risk-free curve, provided by EIOPA, interpolating the curve in the corresponding duration;
- we compute the risk-correction curve, defined as the 30% of the LTAS (long term average of spread, provided by EIOPA), if the bond issuer belongs to the EURO area, 35% otherwise.
- summing the market interest rate curve and the risk-correction curve, we obtain the risk-corrected curve, and we interpolate this curve in the corresponding duration, obtaining the risk corrected market yield.

Considering the weights of the representative portfolio of central government and central banks bonds, we therefore have obtained three portfolios of zero coupon bonds. We thus compute the IRR of these three portfolios:

- IRR1 for the market yield before risk correction portfolio;
- IRR2 for the Basic Risk Free Rate portfolio;
- IRR3 for the risk corrected market yield portfolio.

A.2 Country/currency - Corp

The procedure is the same as above, substituting the bond issuers with asset classes provided by EIOPA. In fact the composition of the country representative portfolio of assets other than central government and central banks bonds is given, dividing the assets in financial and non-financial, and then dividing both classes according to the investment grade.

Another difference is that the risk correction is defined as

$$RC = \max\{35\% LTAS, PD + CoD\},$$

PD (CoD) being the Probability of Default (Cost of Downgrade), provided by EIOPA.

In some cases the representative portfolio of assets other than central government and central banks bonds can contain one or more countries. In this case the procedure is the same as in Section A.1, with the risk-correction equal to 35% of the LTAS.