2020 review of Solvency 2

Interest rate risk capital charge

December 2024

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4, rue Chauveau-Lagarde - 75008 Paris
T. 01 44 51 72 72
secretariat@institutdesactuaires.com
www.institutdesactuaires.com
Association loi de 1901, reconnue d'utilité publique

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Executive summary

As part of the ongoing 2020 review of Solvency II, the Prudential Commission of the French Institute of Actuaries established a working group in April 2023 to reassess the interest rate risk capital charge within the Solvency II standard formula. This reassessment was driven by the unique inflationary environment observed in 2022 and 2023, and the incorporation of new data since the last EIOPA calibration studies.

This document introduces a new calibration of interest rate risk parameters, reflecting the latest data up to the first quarter of 2024. The calibration is grounded in statistical studies and validated by reproducing and comparing EIOPA results with the new calibration. Additionally, the paper proposes an approach to mitigate the impact of inflation in extreme scenarios through a corridor based on the European Central Bank's targets.

Key proposals include:

1. **Recalibration of Interest Rate Shocks**: The document advocates for a methodology change to better capture economic dynamics and ensure sound risk management. The proposed shocks, derived using quantile regression, offer a more accurate adaptation to changing economic conditions.
2. **Inflation Volatility Management**: A new approach is suggested to mitigate the impact of inflation in extreme scenarios. This involves applying a corridor based on the European Central Bank's targets to adjust the risk-free interest rate shocks in case of excess inflation.
3. **Comprehensive Proposal**: The document outlines a comprehensive framework that balances robustness with flexibility, aiming to minimize the need for frequent revisions in response to changing economic conditions.

The working group's findings, detailed in the appendices, underscore the importance of addressing interest rate shocks within the prudential framework, especially given the significant fluctuations in interest rates observed in recent years. The evolving economic landscape necessitates a thorough examination of how these shocks are measured to ensure the solvency of insurance undertakings and promote proper risk management.

1. Introduction

The 2020 review of Solvency II has prompted a comprehensive reassessment of the interest rate risk capital charge within the Solvency II standard formula. This review began at a time when the primary focus was on managing the challenges posed by low and negative interest rates. However, as the review progressed, the economic landscape shifted dramatically. Interest rates began to rise at an unprecedented pace, driven by a combination of factors including the aftermath of the COVID-19 pandemic, disruptions in global supply chains, and geopolitical tensions such as the war in Ukraine. These conditions led to a significant surge in inflation during 2022 and 2023, further complicating the risk management landscape for insurers.

In April 2023, the Prudential Commission of the French Institute of Actuaries established a dedicated working group to address these evolving challenges. Over the course of eighteen months, this group has conducted extensive studies and analyses to develop a new calibration of interest rate risk parameters that better reflect the current economic environment. The exceptional inflationary period during which the group began its work underscored the need for a more dynamic and responsive approach to risk management.

The group's concerns centered on the inadequacies of the existing Solvency II calibration for interest rate risk, particularly in light of the new data and economic realities that have emerged since the last EIOPA calibration studies. While EIOPA's extensive work has provided a solid foundation, the working group identified certain shortfalls and the need to update analyses and calibration studies. One of the key methodologies proposed in the working group analysis is quantile regression, which allows for a more nuanced understanding of the distribution of interest rate changes and provides a better fit for the observed data.

In addition to recalibrating the interest rate shocks, the working group also focused on the impact of inflation volatility. Given the significant role that inflation plays in the current economic landscape, it was essential to develop a mechanism that could mitigate its effects in extreme scenarios. The proposed solution involves the use of an inflation corridor based on the European Central Bank's targets, which adjusts the risk-free rate shocks for excess inflation. This approach aims to provide a more stable and predictable framework for managing interest rate risk.

Please note that this document is limited to the liquid part of the yield curve, in accordance with the work carried out by EIOPA for the 2020 review of Solvency II. The application of the interest rate shocks on the illiquid part of the curve and the discussions around convergence towards the UFR have been considered as a distinct subject and outside the scope of this study.

The findings and proposals of the working group are detailed in this document, which serves as a comprehensive guide to the new calibration and its implications. The appendices provide additional context and validation for the proposed changes, including a comparison with the results of previous EIOPA studies. This thorough documentation ensures that stakeholders have a clear understanding of the rationale behind the new calibration and the expected benefits for the insurance industry.

In conclusion, the 2020 review of Solvency II represents a critical opportunity to enhance the prudential framework for interest rate risk. The exceptional inflationary period of 2022 and 2023 underscored the need for a more dynamic and responsive approach to risk management. The proposals put forward by the working group aim to address these challenges and provide a robust foundation for the future. By incorporating the latest data and advanced statistical methods, the new calibration is designed to ensure the solvency of insurance undertakings and promote sound risk management practices in an increasingly volatile economic environment.

2. Motivation for a review of interest rate shocks

Background elements

Original calibration of interest rate risk was detailed in “The underlying assumptions in the standard formula for the Solvency Capital Requirement calculation” (EIOPA-14-322 from 25/07/2014) stating that data gathered “*EUR government zero coupon term structures (1997 to 2009) [...] and both Euro and GBP LIBOR/swap rates (1997 to 2009)*” (GBP government term structures were also used).

Calibration was discussed in “EIOPA’s second set of advice to the European Commission on specific items in the Solvency II Delegated Regulation (EIOPA-BoS-18/075 from 28/02/2018)” where EIOPA stated that “*data history goes up to 17 years of daily observations depending on the currency*”.

The last paper on the topic is the “Background document on the opinion on the 2020 review of Solvency 2” (EIOPA-BoS-20/750 from 17/12/2020) stating that “*EIOPA reviewed the current calibration of the interest rate risk sub-module from 2017 to 2018. Strong evidence was gathered demonstrating that the current approach for calculating capital requirements for interest rate risk leads to a severe underestimation of the risks [...] The calibration set out in the Delegated Regulation was not changed when the European Commission amended that Regulation in 2019. [...] The calibration carried out in 2017/2018 was based on data from 1999 to 2016. By now, two additional years of data of 2017 and 2018 can be added to the time series. [...] After the public consultation of the advice from October 2019 to January 2020 the calibration was reviewed again based on date up to August 2020*”.[1]

The current calibration of the rate shock and the proposed reviewed shocks are based on data covering period of relatively stable inflation and decreasing interest rates in most regions of the world. For illustration, the two following charts present EIOPA’s proposal for revised shocks and how they affect the yield curve and its shape.

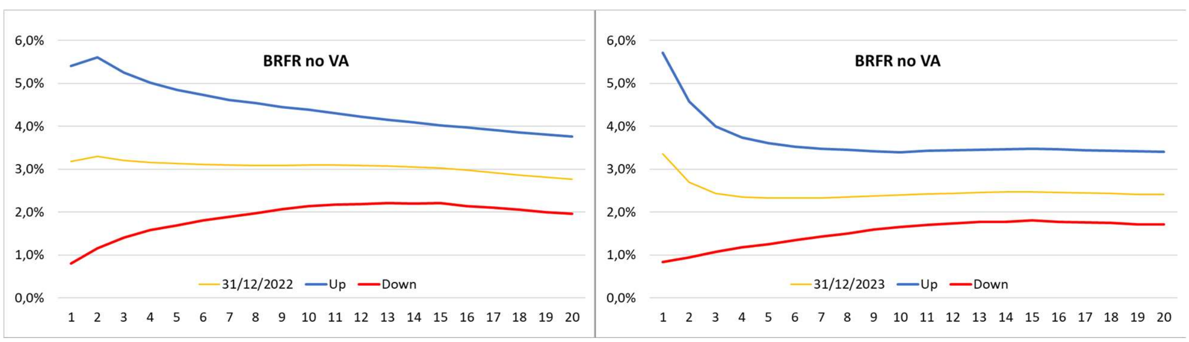


Chart 1. New shocks to interest rates

The severity of shocks, and consequently the capital charge for interest rate risk, has increased. Historical evidence underscores the necessity of reviewing the interest rate capital charge, emphasizing the need for a data-driven shock with robust justification.

Recent industry developments

While interest rates have been on a downward trend since the early 1980s, the break in the rate trend initially observed in 2022 is confirmed in 2023 and beyond, with a return of inflation which, after peaking at the end of 2022, remains above the ECB's 2% target. The main causes of this inflation are the increase in the money supply to support the economy affected by the pandemic, as well as pressure on energy and commodity prices resulting from the disruption of the supply chain post COVID and the war in Ukraine.

[1] Since the shocks presented in EIOPA-BoS-18/075 and those in EIOPA-BoS-20/749 (Opinion on the 2020 review of Solvency II) and EIOPA-BoS-20/750 (Background document on the opinion) are identical, the following of the note will not differentiate them and refer to one or the other interchangeably.

From 2022, the scenario most generally used to calculate the Solvency II ratio became the upward scenario, since it became more penalizing than the downward scenario, with a direct impact on the amount of capital to be covered. This rising rate scenario will have an impact on the market value of assets, variable cash flows (e.g., profit-sharing policies), discounting of cash flows, lapses and expenses depending on modeling choices, the absorption capacity of technical provision and deferred taxes to ultimately determine the solvency ratio.

Inflation surge

As recalled in AAE's position paper[2] on inflation risk management, inflation results from supply and demand forces and future inflation expectations. Governments may increase the money supply to stimulate the economy, potentially causing inflation. Central banks, for their part, manage inflation through monetary policy. Controlled, stable inflation is usually retained as beneficial for economic planning and investment.

Monetary and government policies are anticipated by the interest-rate market. For example, the swap curve flattened in 2022 and inverted in 2023, suggesting that the market anticipated a more aggressive monetary policy, particularly in the short term, with a focus on the potential for higher long-term rates.

In this complex and uncertain context, calibrating an interest rate shock represents a genuine challenge. The shock must be calibrated to a bicentennial risk, while available data do not allow to easily distinguish and account for different states of the economy and inflation for calibration purposes.

We recall the underlying assumptions in the standard formula for the Solvency Capital Requirement calculation[3]:

- *"Only interest rate risk that arises from changes in the level of the basic risk-free interest rates is captured.*
- *Volatility and changes in the shape of the yield curve are not covered explicitly in the interest risk sub-module.*
- *The undertaking is not exposed to material inflation or deflation risk."*

The third assumption posits that the undertaking is not subject to inflation risk, which is currently inaccurate. The graph below illustrates that inflation levels have remained uncontained since late 2021. Furthermore, historical data reveals periods of inflation below 1% accompanied by relatively high volatility (e.g. in 2014).

[2] See AAE discussion paper 'A Primer on Inflation Risk Management' - Actuarial Association of Europe (actuary.eu)

[3] See « The underlying assumptions in the standard formula for the Solvency Requirement calculation », EIOPA-14-322, https://register.eiopa.europa.eu/Publications/Standards/EIOPA-14-322_Underlying_Assumptions.pdf

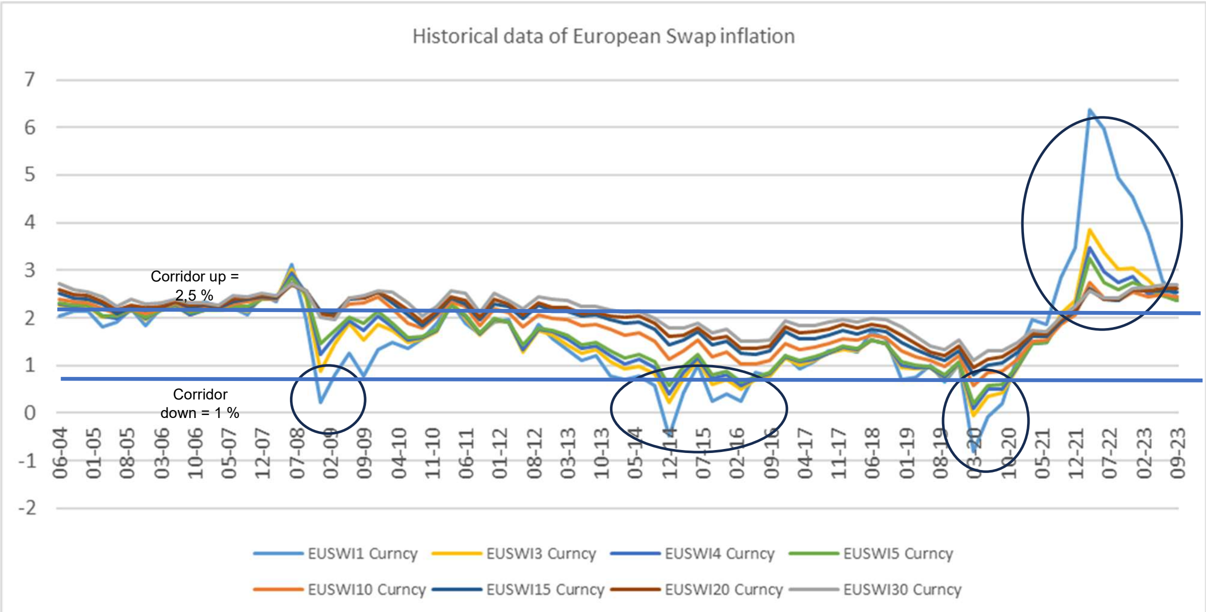


Chart 2. Historical inflation data

In 2022 and 2023, zero-coupons for low maturities went above the ECB target, reaching 6% for the 1-year maturity in 2022. For maturities above 10 years, nearly all data points are included between 1% and 2,5%. Market anticipates a return to more contained inflation levels, but for all maturities, inflation remains above the ECB target.

This inflation volatility peaks lead to the definition of an inflation corridor bounded by a lower limit of 1% and an upper limit around 2,5 % around the ECB target (set at 2%). The purpose of this corridor will be discussed in part 4 below.

Furthermore, an analysis of the nominal rates and inflation at the end of 2022 and 2023 reveals that nominal interest rates are predominantly driven by inflation. Real rates are zero or even negative across many maturities by the end of 2023.

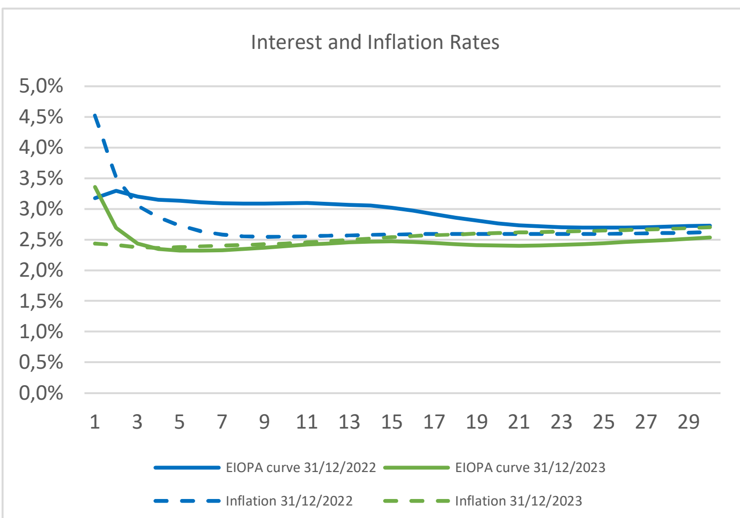


Chart 3. Interest rates compared to inflation

Current methodology that links magnitude of shocks to the level of interest rates (through a multiplicative factor) will produce in such a case to shock whose magnitude is driven by inflation level.

Volatility surge

Beyond the attention paid to inflation, extensive work was conducted on the calibration performed by EIOPA for interest rate shocks. The motivation was to account for new data available since the last calibration performed by EIOPA (EIOPA's "Opinion on the 2020 review of Solvency 2"[4]). Our work, detailed in the Appendix 3. ("Reconstruction of EIOPA's calibration of interest rate risk", see page 18), reproduced the calibration of the shocks and extended the calibration to the newest data available.

During the 2018 review of Solvency 2, EIOPA tackled the issue of negative rates introducing a θ parameter (i.e. a shift to interest rates). This shift allowed EIOPA to compute relative annual changes in interest rates ("delta rates") even when rates were near zero. However, this methodology proved inadequate for the updated dataset as the data shift failed to deal with volatility in the data and produce economically sound results.

A gist of the challenge faced is illustrated by Chart 4. below. It displays the changes in interest rates calculated from the most recent data, highlighting the increasing volatility of the computed 'delta rates' in recent years. Consequently, statistics derived from this dataset using the current methodology may be disproportionately influenced by the latest observations. However, it is important to note that discarding data, particularly recent observations, is not the preferred approach and should be reserved for exceptional circumstances.

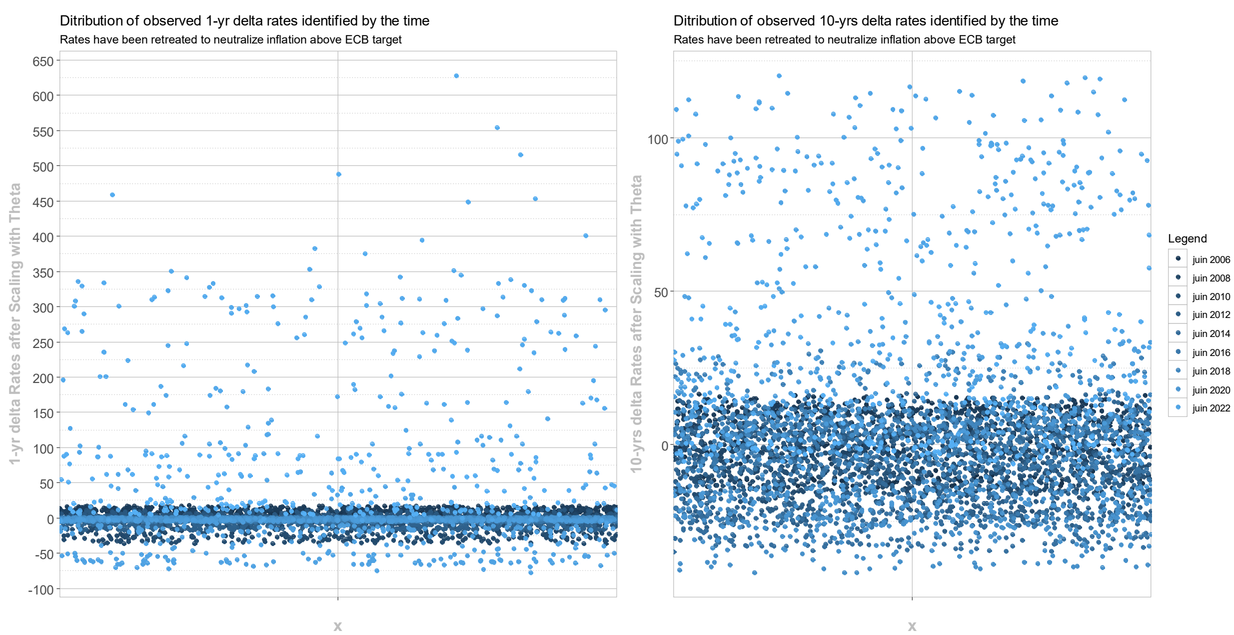


Chart 4. Distribution of delta rates

This chart illustrates that recent data exhibit significantly wider fluctuations compared to older data.

[4] EIOPA-BoS-20/749 from 17 December 2020

3. Proposal for a recalibration of interest rate shocks

The case for a methodology change

Given the unsatisfactory results from extending the data window, while replicating EIOPA's methodology, it appeared necessary to revise the methodology behind shocks evaluation. Ideally, any new methodology ought to encompass several essential criteria.

Firstly, it must incorporate all available data, avoiding the exclusion of data labeled as "outliers", especially in this prudential context where an estimation of quantiles is pursued. Secondly, it should account for fluctuations in the economic environment and dynamics described earlier. Most importantly, the resulting shock parameters should incentivize sound risk management, ensuring that the shocks are neither excessively high nor unduly low.

Quantile regression - Background theory

Quantile regression is a statistical method that is used to estimate quantiles described by R. Koenker and G. Bassett in 1978[5]. The basic idea is to define the τ-quantile of Y given X[6]:

$$Q_{Y|X}(\tau) = inf\{y \big| F_{Y|X}(y) > \tau\}$$

Assuming that the quantile is given by a linear function of explanatory variables[7]:

$$Q_{Y|X}(\tau) = X\beta_\tau$$

The estimator of β is given by:

$$\widehat{\beta_\tau} = arg\min_{\beta} \frac{1}{N}\sum_{1}^{N}\big(\rho_\tau(Y_i - X_i\beta)\big)$$

Where N is the sample size and ρ is the tilted absolute value function:

$$\rho_\tau(u) = (\tau - I_{u\leq 0})u$$

Having set these background elements, interest rates variations are computed for a given maturity *m* by applying the one year rolling window assumption, i.e.:

$$\Delta r_t = r_t - r_{t-\omega} \text{ where } \omega\text{=260 for 260 business days}$$

Those variations are regressed against interest rates to produce an estimate for the quantiles of interest rate shocks:

$$\widehat{\Delta r_t}^{up,down}(m) = r_t(m) \times s_m + b_m$$

Note that the use of EIOPA's notation is intentional, as this paper aims to propose a framework consistent with the general understanding prevalent in the market since EIOPA's papers on the review.

It should also be noted that the general approach adopted here is identical to that of EIOPA, where quantiles by maturity are used to construct shocked curves[8].

[5] See https://gib.people.uic.edu/RQ.pdf
[6] See https://en.wikipedia.org/wiki/Quantile_regression
[7] When the relation between the variable is not linear, the methodology can be expanded to more sophisticated functions. See for instance https://cran.r-project.org/web/packages/quantreg/vignettes/rq.pdf for some examples. Tests have been performed with a 3-degree polynomial. The additional quality in quantiles estimation did not appear, at least in a first approach, to be worth the extra complexity in the formula.
[8] This approach could potentially be questioned, arguing that the realization of a 99.5% interest rate risk does not necessarily correspond to a situation where rates simultaneously reach their 99.5% quantile for all maturities. An alternative

Validation on 2018 data

In a first step, calibration is performed on data up to 2018 to test the interest rate shock calibration on the data used by EIOPA in its calibration. In the following chart grey dots associate the observed interest rate level (x axis) and change in interest rate observed in the following year (y axis). The objective, for prudential purpose, is to estimate the quantiles of these changes to estimate the shocks to apply. Shocks are computed on the 1-year maturity rate according to EIOPA's methodology (blue dashed lines) and derived from quantile regression (red solid lines). Shocks calibrated with EIOPA's methodology appear to be more severe while both models lead to the same pattern i.e. shocks becoming increasingly severe as rates rise.

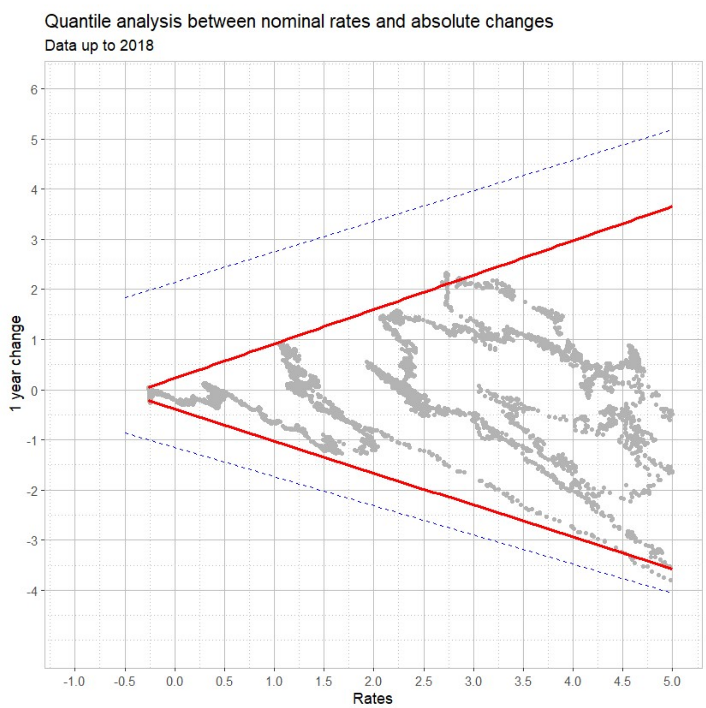


Chart 5. Quantile regression on data up 2018

Noticeably, for rates above (approximately) 3%, both methodologies give upward shocks more severe than any observed data.

approach could, for example, involve a principal component analysis to identify a common risk factor and derive the quantiles of this risk factor. The work presented has not, at this stage, incorporated the possibility of such an alternative approach.

Complete dataset with 2024 data

Adding data from 2018 to 2024 impacts significatively estimates derived with quantile regression. Results plotted on the following chart (Chart 6.

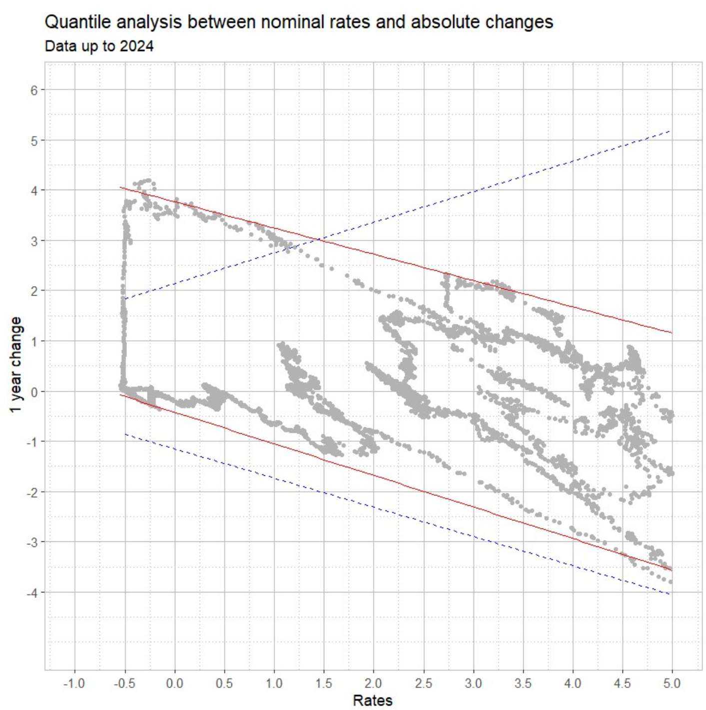


Chart 6. Quantile regression on data up 2024 on 1-year interest rate

Results presented necessitate further discussion.

First, EIOPA's shocks displayed above are computed on 2018 data (aforementioned "Opinion on the 2020 review of Solvency 2"). Update of the parameters were performed (see below and "Expanding data up to 2024" on page 22). This update yielded results that were considered unsatisfactory as they led to shocks above any historical evidence.

Moreover, the new data integrated after 2018 notably corresponds to the emergence of economic realities that were absent from the previous sample.

The alteration in quantile estimation due to the incorporation of new data is not inherently a sign of a lack of robustness (irrespective of the method employed, EIOPA or quantile regression). Firstly, the additional data spans six years, and the inclusion of a few points is unlikely to significantly affect the estimators. Furthermore, some of the new data pertain to a specific rate regime of inflation and real rate volatility, which has been elaborated upon in the appendix (see for instance Chart 17. on page 24).

Finally, although this methodology does not explicitly account for heteroskedasticity[9] or, more broadly, for changes in underlying economic dynamics, it nevertheless yields results that align more closely with common sense. Specifically, in environments of low or negative rates, upward shocks should be amplified relative to downward shocks, and conversely, when rates are already high. Decreasing red lines convey this idea.

[9] Heteroskedasticity has not yet been fully dealt for in this note, see https://cran.r-project.org/web/packages/quantreg/vignettes/rq.pdf for some discussion on the topic.

For the sake of completeness, changes in 10-year maturity interest rates over a one-year horizon are displayed in the following chart. Noticeably, quantile regression led to shocks higher than EIOPA's at least for rates below 3.25%.

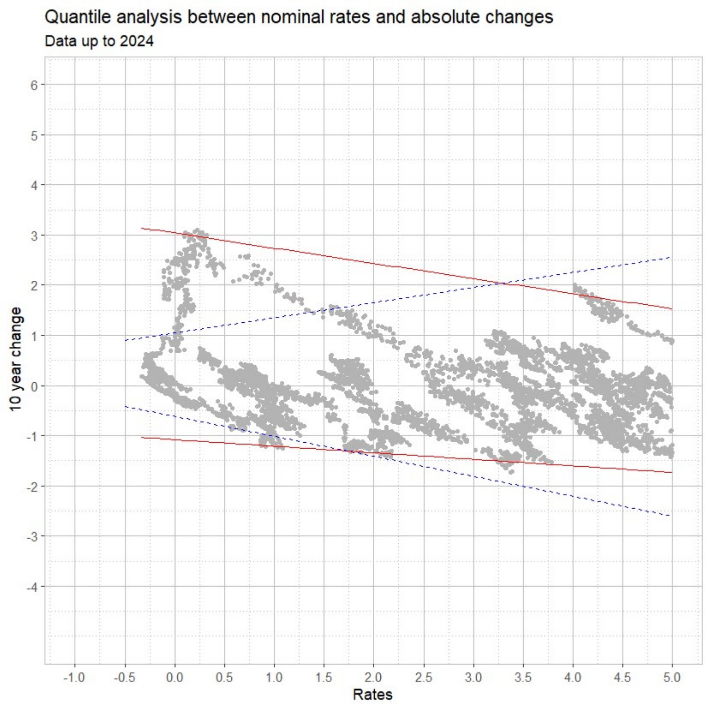


Chart 7. Quantile regression on data up 2024 on 10-year interest rate

Illustratively, we present below the graph of the shocks on 1-year interest rates with EIOPA's final opinion parameters re-estimated using data extended until 2024. The re-estimation work is extensively detailed in Appendix 3. (see "Expanding data up to 2024" on page 22). Inclusion of additional data leads to an intensification of the shocks as materialized by difference between blue dashed lines (final opinion) and black dot-dashed bold lines (final opinion re-estimated).

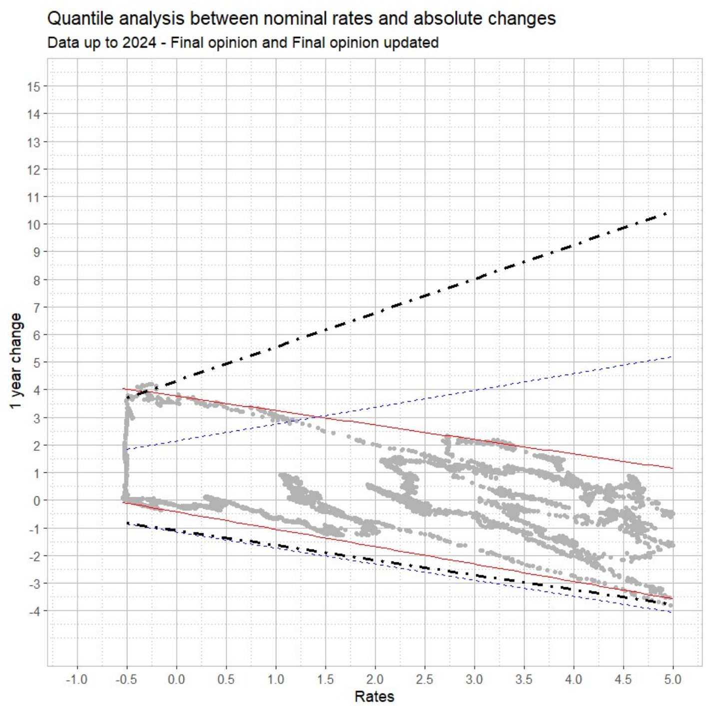


Chart 8. Quantile regression and update of final opinion on data up 2024 (1-yr rate)

Proposed interest rates shocks

The shock as calibrated with quantile regression and proposed for computation of interest rate risk in the standard formula of Solvency 2 are the following:

Maturity	s_{down}	b_{down}	s_{up}	b_{up}
1	-69	-0,44	-53	3,77
2	-58	-0,45	-45	3,56
3	-47	-0,52	-38	3,37
4	-38	-0,60	-36	3,25
5	-31	-0,72	-35	3,19
6	-25	-0,81	-33	3,16
7	-20	-0,88	-32	3,12
8	-16	-0,97	-32	3,09
9	-13	-1,04	-32	3,07
10	-10	-1,13	-31	3,05
15	-1	-1,49	-29	2,91
20	0	-1,58	-24	2,63
30	3	-1,68	-18	2,21

4. Proposal for shocks better suited to inflation volatility

Proposed mechanism

As part of its work, the Prudential Commission of the French Institute of Actuaries suggests a new proposal for the interest rate shock based on the observations made below:

- The evolution of real interest rates and inflation are not univocally linked, calling into question the need to apply a uniform stress factor to them in the context of the interest-rate SCR.
- The current stress level (i.e. before 2020 review), although applied to nominal rates, is mainly based on real-rate volatility as inflation was stable around 2% over the calibration period. Most recent volatility in interest rates was significantly driven by inflation volatility.

An intuitive approach would be to stress the real and inflation components independently, leading to separate calibration work on each component of the nominal rate. Such an approach would come with its share of challenges about calibration of multiple parameters and the correlation between them.

The working group considered an alternative method, keeping as a guiding principle the idea of differentiated stress between real rates and inflation. Two additional requirements were added: the method should be deployable for both upward and downward rate shocks, and it should be compatible with the adjustments recommended as part of the review of the standard formula.

Our approach is to avoid shocking the inflation excess (respectively inflation shortage). This “excess” (respectively “shortage”) corresponds to the share of inflation in excess of (respectively below of) the 2% target set in the ECB's mandate. Based on our previous discussion (see Inflation surge, page 4) we introduce a minimum limit (1%) and an upper limit (2,5%) around the ECB target (2%) to define a corridor.

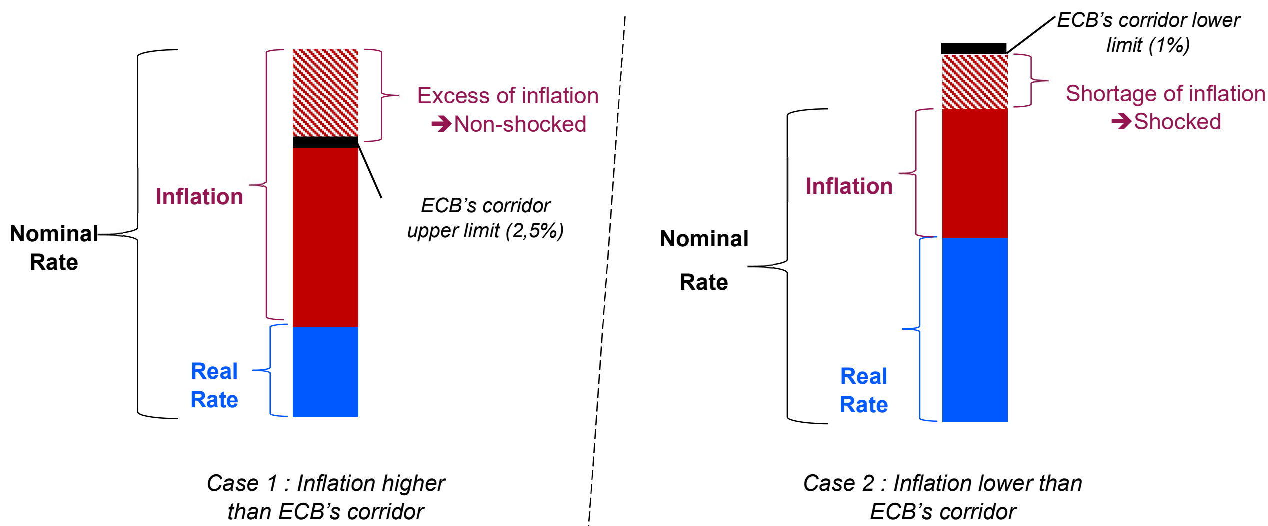
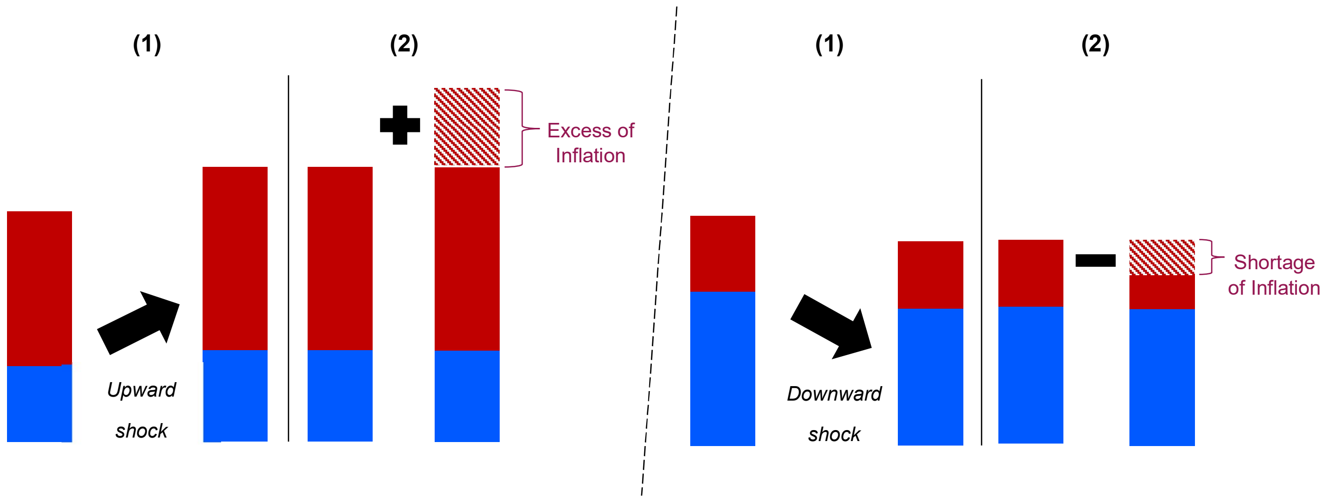


Chart 9. Shock applied outside ECB corridor

In practice, this means applying the standard formula shock to the real rate, plus the ECB's inflation target (1), then incorporating the inflation surplus without applying a distortion (see step 2 on the chart below).



Case 1 : Upward shock with Inflation higher than the ECB's corridor higher bound

Case 2 : Downward shock with Inflation lower than the ECB's corridor lower bound

Chart 10. Interest rate after application of a shock limited to ECB

The operational approach is as follows:

Step 1: Calculation of the risk-free rate adjustment for excess of inflation

If $ZCIS_t > ECB\ Target\ Max$ *then* $r_t^{adj} = \frac{(1+r_t)\times(1+ECB\ Target\ Max)}{(1+ZCI\ _t)} - 1$

If $ZCIS_t < ECB\ Target\ Min$ *then* $r_t^{adj} = \frac{(1+r_t)\times(1+ECB\ Target\ Min)}{(1+ZCIS_t)} - 1$

With:

- r_t *: the risk-free rate for maturity t*
- $ZCIS_t$ *: the zero-coupon inflation swap rate for maturity t*
- $ECB\ Target\ Max$ *: the upper bound for the ECB corridor: 2,5%*
- $ECB\ Target\ Min$ *: the lower bound for the ECB corridor: 1%*

Step 2: Application of upward or downward shock

$r_t^{adj}(up) = r_t^{adj} \times (1 + s_m^{up}) + b_m^{up}$

$r_t^{adj}(down) = \max(-1{,}25\%\quad ; r_t^{adj} \times (1 - s_m^{down}) - b_m^{down})$

With :

- s_m^{up} *: the multiplicative factor of the upward shock*
- b_m^{up} *: the additive factor of the upward shock*
- s_m^{down} *: the multiplicative factor of the downward shock*
- S_m^{down} *: the additive factor of the downward shock*

Note: The approach is similar to the approach defined in the review of the standard formula. The only difference is that the shock is applied to a risk-free rate adjusted for the excess of inflation.

Step 3: Application of the excess of inflation to the shocked risk-free rate

If $ZCIS_t \ > ECB\ Target\ Max$ then $r_t(up) = \left(1 + r_t^{adj}(up)\right) \times \frac{(1+r_t)\times(1+ZCI\ _t)}{(1+ECB\ Target\ Max)} - 1$

and $r_t(down) = \left(1 + r_t^{adj}(down)\right) \times \frac{(1+r_t)\times(1+ZCIS_t)}{(1+ECB\ Target\ Max)} - 1$

If $ZCIS_t \ < ECB\ Target\ Min$ then $r_t(up) = \left(1 + r_t^{adj}(up)\right) \times \frac{(1+r_t)\times(1+ZCI\ _t)}{(1+ECB\ Target\ Min)} - 1$

and $r_t(down) = \left(1 + r_t^{adj}(down)\right) \times \frac{(1+r_t)\times(1+ZCIS_t)}{(1+ECB\ Target\ Min)} - 1$

Historical Perspective and Back-testing

The proposed approach has been tested on three different rate levels and compared with the current approach as envisaged in the review of the standard formula.

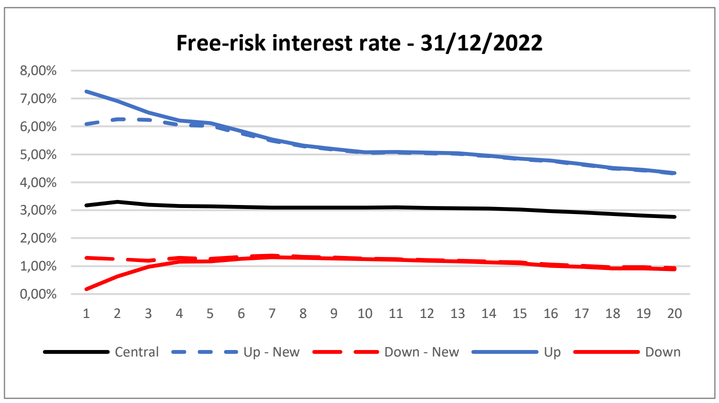


Chart 11. 31/12/2022 - Application of the corridor in high rates situation

The over-inflation primarily present in the early years of the interest rate curve is corrected in the intensity of the new shock. However, the intensity of the shock is deemed to remain significant and economically meaningful.

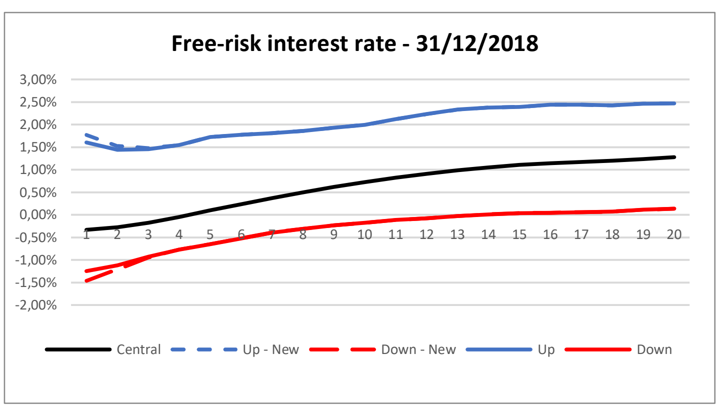


Chart 12. 31/12/2018 - Application of the corridor in low rates situation

In the low-rate situation, the shock obtained with the proposed formula is slightly stronger. This is explained by the correction for under-inflation to reach the minimum 1% inflation target.

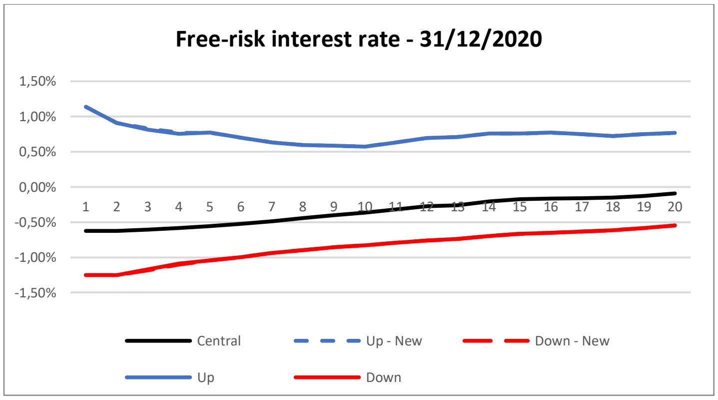


Chart 13. 31/12/2020 - Application of the corridor in negative rates situation

In this last situation, shocks obtained are the same since the level of inflation is in the corridor.

Expected effects

In this proposed approach, interest rate shock is lowered when inflation is abnormally high (respectively increased when inflation is low) while leaving the shock unchanged when inflation is between the ECB targets bounds. We can draw a comparison here with the Symmetrical Adjustment mechanism for equity risks, depending on the level of the equity index in relation to its average over the last 3 years.

It is indeed desirable that the capital charge in a high-inflation, high-interest-rate scenario should not be disproportionate, while ensuring policyholder protection and stability of the financial system. Excessive capital immobilization and volatility of the solvency ratio are not desirable for stakeholders.

5. A comprehensive proposal

In conclusion, our study underscores the importance of addressing interest rate shocks within the prudential framework, especially given the significant fluctuations in interest rates observed in recent years. The evolving economic landscape necessitates a thorough examination of how these shocks are measured to ensure the solvency of insurance undertakings and to promote sound risk management practices.

Summary of Results Achieved

The working group has conducted extensive analyses over eighteen months, focusing on the recalibration of parameters associated to interest rate shocks. The primary results include the identification of inadequacies in the existing Solvency II calibration, particularly in light of the new data and economic realities that have emerged since the last EIOPA calibration studies. The group proposed a robust statistical method for quantile estimation, which is designed to be applicable across a wide range of different environments. This method provides a reliable measure that can adapt to various economic conditions, thereby enhancing the accuracy and effectiveness of the solvency framework.

Comprehensive Proposals

The comprehensive proposal puts forward two elements developed by the working group:

- **Recalibration of Interest Rate Shocks**: The group proposed a methodology change to better capture economic dynamics and ensure sound risk management. The proposed shocks, derived using quantile regression, offer a more accurate adaptation to changing economic conditions. This method allows for a more nuanced understanding of the distribution of interest rate changes and provides a better fit for the observed data.

- **Inflation Volatility Management**: Given the significant role that inflation plays in the current economic landscape, the group developed a mechanism to mitigate its effects in extreme scenarios. The proposed solution involves the use of an inflation corridor based on the European Central Bank's targets, which adjusts the risk-free rate shocks for excess inflation. This approach aims to provide a more stable and predictable framework for managing interest rate risk.

The way the two proposals can be combined in practice is still being considered by the working group and may be addressed in an upcoming update of the note.

Value of the Proposal

The value of this comprehensive proposal lies in its ability to address the shortcomings of the current Solvency II framework[10]. By incorporating the latest data and advanced statistical methods, the new calibration is designed to ensure the solvency of insurance undertakings and promote sound risk management practices in an increasingly volatile economic environment. The proposed quantile regression method enhances the precision of risk assessments, while the inflation corridor provides a mechanism to stabilize the impact of inflation on interest rate shocks.

Impact on the Review of Solvency II

We suggest that this comprehensive proposal be considered in the ongoing review of Solvency II. The exceptional inflationary period of 2022 and 2023 has underscored the need for a more dynamic and responsive approach to interest rate risk. The proposals put forward by the working group aim to address these challenges and provide a robust foundation for the future. By integrating this comprehensive proposal into the Solvency II framework, regulators can ensure that the framework remains effective and relevant in the face of evolving economic conditions.

Current Options and Their Limitations

The current options on the table for the Solvency II review are not suitable in light of recent data. The existing calibration methods do not adequately account for the fluctuations in interest rates and inflation observed in recent years. The proposed quantile regression method and inflation corridor offer a more accurate and reliable approach to managing these risks. The working group's analyses have demonstrated that the current methods may lead to inconsistent consequences, even in scenarios of low or negative interest rates. The alternative proposal developed by the group aims to mitigate these impacts and provide a more stable and predictable framework for risk management.

Conclusion

In conclusion, the 2020 review of Solvency II represents a critical opportunity to enhance the prudential framework for interest rate risk. The exceptional inflationary period of 2022 and 2023 has highlighted the need for a more dynamic and responsive approach to risk management. The comprehensive proposal put forward by the working group combines advanced statistical methods with practical mechanisms to stabilize the impact of inflation. By incorporating these proposals into the Solvency II framework, regulators can ensure that the framework remains robust and effective in a volatile economic environment. This balance is crucial for maintaining financial stability and fostering confidence in the regulatory system.

[10] For comparison of the various methodologies in past occurrences, refer to Appendix 4. where the proposal is tested in 2019, 2020 and 2022.

6. Appendices

Appendix 1. Proposal from the Prudential Commission on the downward shock

On November 30, 2021, during the joint event held by the French Institute of Actuaries and French supervisor ACPR[11], French institute presented what was called the "semi-multiplicative shock". On this date, the profession was concerned with interest rates regularly reaching record lows.

The formula presented was:

$$r_t^{down}(m) = r_t\ (m) - \max\left(0; r_t\ (m) \times s_m^{down}(\theta_m)\right) - b^{down}$$

Where :

- The multiplicative shock is applied only on positive rates.
- b^{down} is set at 30 bps, this value being calibrated on the 99,5% quantile of the 1-year annual variations, when this rate is negative.
- Absolute floor is discarded.

The underpinning motivation for this shock was twofold:

- Observed statistical evidence on the 1-year rate that volatility is reduced when rates cross the 0% threshold and sail in negative territories. Not enough data are available to calibrate a distinct b^{down} by maturity.
- Absolute floor was deemed not to be sensible at a time of historical lows being regularly reached. The shock was designed in a robust way that would not require a revision should a new record be recorded.

Appendix 2. Proposal based on yield curve inversion

Motivation

This appendix aims to provide insights and document the work performed by the working group for a tentative that did not deliver satisfactory results. A mechanism symmetrical to the "downward rate proposal" was studied by the working group. This mechanism would have captured unusual shapes of the BRFR curve.

More specifically, tests have been performed to check whether an inversion of the curve between the liquid part and the UFR would justify differentiated shocks. Such differentiated shocks would be motivated were a statistically significant change in volatility be observed depending on the shape of the curve. Inversion of the liquid part of the curve was not studied since the motivation was to extend the "semi-multiplicative" methodology and explore whether an absolute threshold could be defined, above which a differentiated shock would be justified.

Results

The tests carried out showed no statistically significant effects using a standard p-value of 5%.

- **<u>Description of the dataset</u>**

Tests were performed on daily and monthly data from a history of one-year, two-year and ten-year swap rates.

We selected four methods to ensure an exhaustive assessment of the disparity between the samples, thus providing a sound statistical basis for interpreting any significant differences.

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[11] To avoid any ambiguity, it should be clarified that these events do not constitute an official communication channel of the supervisor, and points raised by the institute are neither endorsed nor disapproved by ACPR. Video is available online (in French) at https://www.institutdesactuaires.com/se-documenter/supports-des-presentations/conferences-acpr-institut-des-actuaires-1942.

Indeed, to assess this variability, the Fisher, Levene, Bartlett and Fligner-Killeen tests were chosen. It should be noted that the Chi-square test is not suitable for this study, as the values studied are less than 5 and do not follow a normal distribution. Hence the use of the Fisher test for its robustness to this condition, while the Levene, Bartlett and Fligner tests were employed to complete the evaluation, considering different distribution conditions.

As described above, all statistical tests carried out show no significant difference which suggests consistent evidence across different methods and consistently point in the same direction. This alignment strengthens the validity of our findings.

Appendix 3. Reconstruction of EIOPA's calibration of interest rate risk

Background elements

- **Data**

Interest rates data are taken from Bloomberg with tickers EUSA*xx*, where *xx* stands for maturity.

Inflation is obtained with indices EUSWI*xx*, where *xx* stands for maturity.

Datas were gathered for all working days from the 3rd of January 1999 to 30/04/2024. Missing data are taken care of directly at the extraction by filling missing dates with previous value. Inflation data is available for all indices only after 22/06/2004.

- **Methods**

We faced a challenge when we tried to reconstruct EIOPA's calibration as we did not find a single paper with exhaustive explanation of the methodology but rather bits of information dispersed over several papers published on a span of several years.

CEIOPS-DOC-66/10 from 29/01/2010

> *Our analysis relies on Principal Component Analysis (PCA) to specify the above tabulated scenarios. PCA is proposed as a tractable and easy-to-implement method for extracting market risk. For a collection of annual percentage rate changes, the number of principal components (PCs) to be retained for further analysis is determined by the variance–covariance structure of each underlying data set (i.e., PCA is applied to each individual dataset).*
>
> *[…]*
>
> *The derived PC's or factors are standardised (i.e., have zero mean and unit standard deviation) and are subsequently used in a regression model. The purpose of this model is to calculate the 'beta' sensitivity of each yield to maturity, expressed as annual percentage rate changes, to the above four factors[12].*

EIOPA-CP-16-008

> *The following calibration methodology was applied by CEIOPS in 2009 for each of the data sets considered at that time:*

[12] CEIOPS paper has a footnote here stating: "For a maturity, *m*, we regress the derived annual percentage rate changes on the four PCs to derive the 'beta' sensitivity of each rate to each PC. The combined sum returns the stress factor for maturity *m*."

- *Annual percentage rate changes are computed for each maturity m by applying the one year rolling window assumption, i.e.:*

$$\frac{\Delta r_t}{r_{t-\omega}} = \frac{r_t}{r_{t-\omega}} - 1$$

for each maturity m and where ω=260 for 260 business days.

- *Standardized principal component scores are derived. The interpretation of this step is that the principal component analysis is performed on a standardized data set, that is, instead of considering the covariance matrix of the annual percentage rate changes the PCA is performed on the corresponding correlation matrix.*
- *The annual percentage rate changes derived in step 1 are regressed for each maturity m on the first four standardized principal scores Ti (these are the projected values in the transformed principal component space and not the Eigenvectors!) to derive the so-called beta sensitivity with using OLS regression to obtain the beta values.*
- *This regression model is then fitted with the derived betas:*

$$\frac{\widehat{\Delta r_t}}{r_{t-\omega}} = \sum_{i=1}^{4} \widehat{\beta_l}\, T_i$$

This produces an empirical distribution of the annual percentage rate changes for each maturity.

- *The empirical 99.5 % and 0.5 % quantiles from the distribution yields the required up and down stress factors.*

It is worthwhile emphasizing that the shock factors need not necessarily be derived from the principal component analysis. The methodology described in this section is to use the principal component scores and to derive a mixed (weighted) empirical distribution from which the shock factors are deducted. However, the shock factors could also be computed directly from the empirical distribution or any other suitable parametric distribution for the random shock factors.

EIOPA-18-075[13]

To calibrate the shift approach a reasonable shift parameter needs to be determined in the first step. It is important to note that there is not one correct value for the shift parameter, thus the determination of shift parameter will inevitably require some expert judgement. The shift parameter can be rather considered a meta parameter, which can be set by assessing different criteria. The sensitivity analysis above indicates that when a reasonable range of shift parameters is determined, the model risk is low.

EIOPA has distinguished the shift parameters for the upward and downward stresses.

For the upward shift parameter, it can be estimated non-parametrically by specifying a certain calibration condition. A non-parametric estimation has been performed by minimizing the absolute difference of the stressed curve in the interest rate up scenario under the shifted approach and the current standard formula interest rate up curve interest up curve under the constraint $-1 \leq \theta \leq m < 0$, where m is the smallest negative rate in the calibration data set of the corresponding currency.

[…]

Once the shift parameters are determined, a similar mathematical calibration procedure performed by CEIOPS in 2009 and described in the Discussion paper can be performed. One of the differences introduced is that instead of using a principal component regression on the 4 principal scores to determine the distribution with which the quantiles at 99.5% and 0.5% are determined, the quantiles

[13] https://register.eiopa.europa.eu/Publications/Consultations/EIOPA-18-075-EIOPA_Second_set_of_Advice_on_SII_DR_Review.pdf

were determined on the basis of the empirical distribution of the relative changes. This change has been introduced for the following reasons:

- *First, this was one of the suggestions of stakeholders to ensure that the new calibration passes the back-testing.*
- *Second, the principal component regression requires that the quantiles are derived on the same distributions for all maturities. In other words, the different principal components are derived relatively to each other. Given that maturity dependent shift parameters have been derived, this now appears difficultly feasible.*
- *Third, the results of using the principal component regression or the empirical distribution of relative changes to derive the quantiles actually lead to almost identical results. This can be explained by the fact that the 4 principal components explain almost the entirety of the volatility.*
- *Fourth, this is even simpler.*

[…] the shocked curves under the shifted approach are of the form:

$$r_t^{up,down}(m) = r_t(m) \times a_m + b_m$$

$$a_m = \left(1 + s_m^{up,down}(\theta_m)\right)$$

$$b_m = -\theta_m s_m^{up,down}(\theta_m)$$

Reconstituting EIOPA's previous studies

- **<u>Results for 2009 calibration</u>**

To validate the methodology and dataset, an attempt was made to replicate the calibration of the initial interest rate shocks (those in effect currently, prior to enforcement of the 2020 review). Results are presented in the chart below, with solid lines representing shocks calibrated by EIOPA and triangles represent shock reproduced.

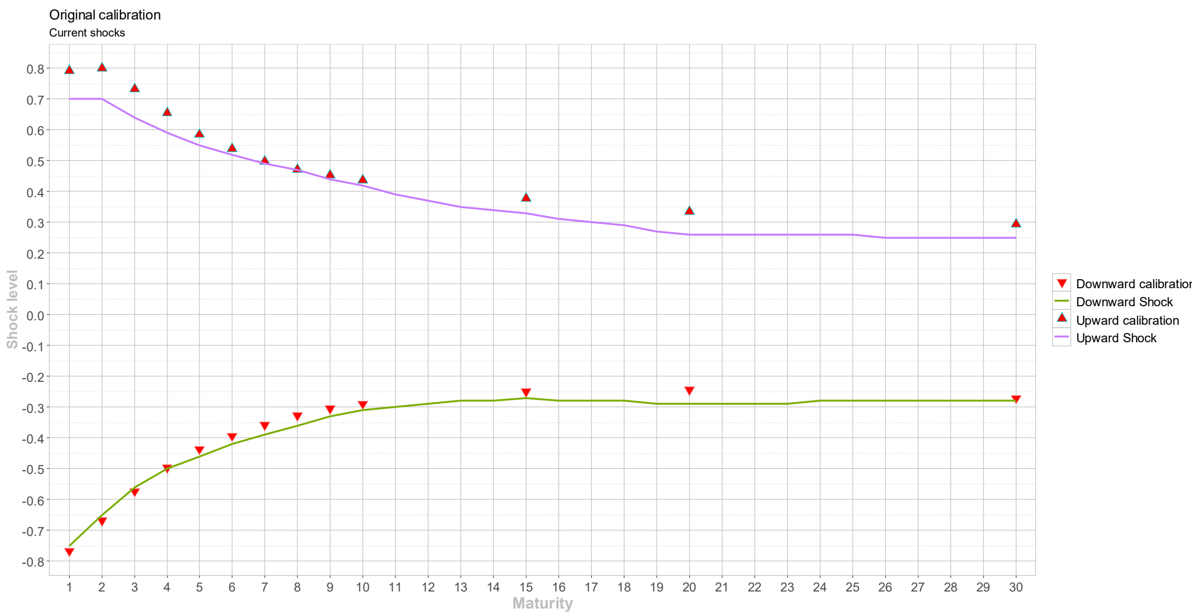

Chart 14. Recalibration of interest rate shocks before review

The chart above shows that shocks are replicated with a magnitude similar to EIOPA's calibration. Small errors are attributed to differences in datasets (e.g., no GBP was used). These errors are deemed to be marginal.

- **<u>Shocks as updated by EIOPA for S2 reviews</u>**

Following the initial validation phase, the shocks were calibrated using data up to 31/12/2018 employing the shift methodology and a θ parameter according to EIOPA's methodology in the review. Solid lines represent current shocks as well as revised shocks calibrated by EIOPA. Triangles represent estimation performed by the working group.

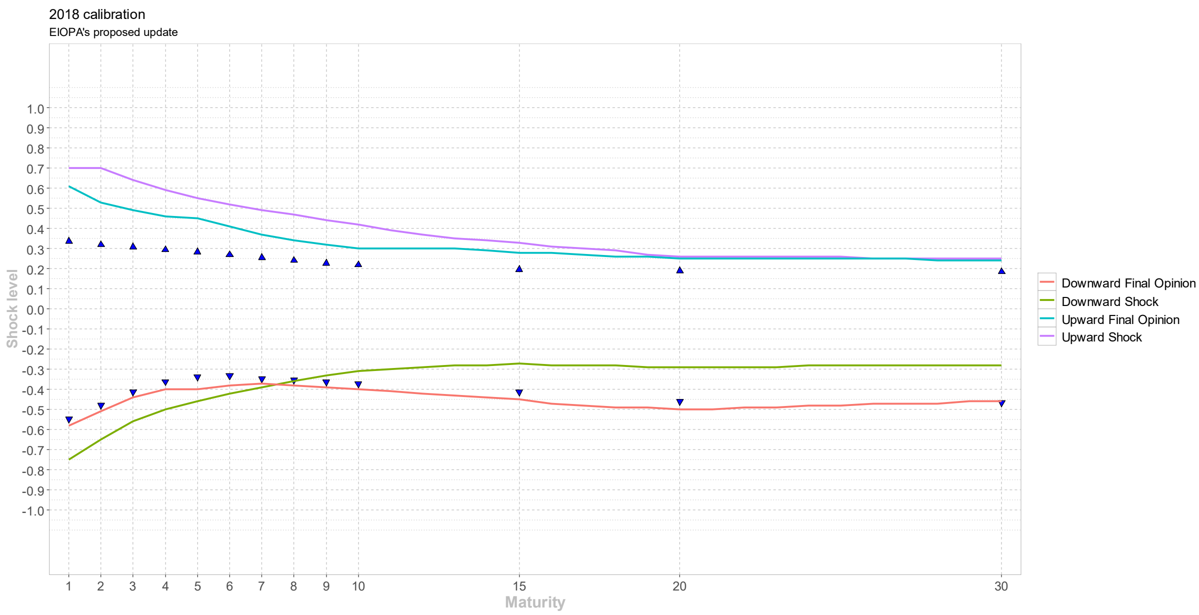

Chart 15. Recalibration of interest rate shocks for S2 review

Working group estimates seem consistent with EIOPA's for the downward shock while the group was not able to reproduce EIOPA's upward shock. Reasons for these discrepancies are likely to lie in data horizons that are not perfectly consistent with EIOPA's data or in the choice of the shift parameter.

The following shock parameters are estimated:

Maturity	s_{down}	b_{down}	s_{up}	b_{up}
1	55	1,09	34	1,18
2	48	0,91	32	1,12
3	41	0,76	31	1,08
4	36	0,65	29	1,03
5	34	0,59	28	0,99
6	33	0,57	27	0,94
7	35	0,57	26	0,90
8	35	0,57	24	0,84
9	36	0,56	23	0,80
10	37	0,56	22	0,77
15	41	0,52	20	0,69
20	46	0,46	19	0,67
30	47	0,47	18	0,65

We recall below the parameters as they have been calibrated by EIOPA for S2 review:

Maturity	s_{down}	b_{down}	s_{up}	b_{up}
1	58	1,16	61	2,14
2	51	0,99	53	1,86
3	44	0,83	49	1,72
4	40	0,74	46	1,61
5	40	0,71	45	1,58
6	38	0,67	41	1,44
7	37	0,63	37	1,30
8	38	0,62	34	1,19
9	39	0,61	32	1,12
10	40	0,61	30	1,05
15	45	0,57	28	0,98
20	50	0,50	25	0,88

Expanding data up to 2024

Analysis performed by EIOPA is reproduced while expanding data up to April 30,2024. The same methodology was kept including the parameter θ with the same values. Solid lines represent current shocks as well as revised shocks calibrated by EIOPA. Triangles represent estimation performed by the working group.

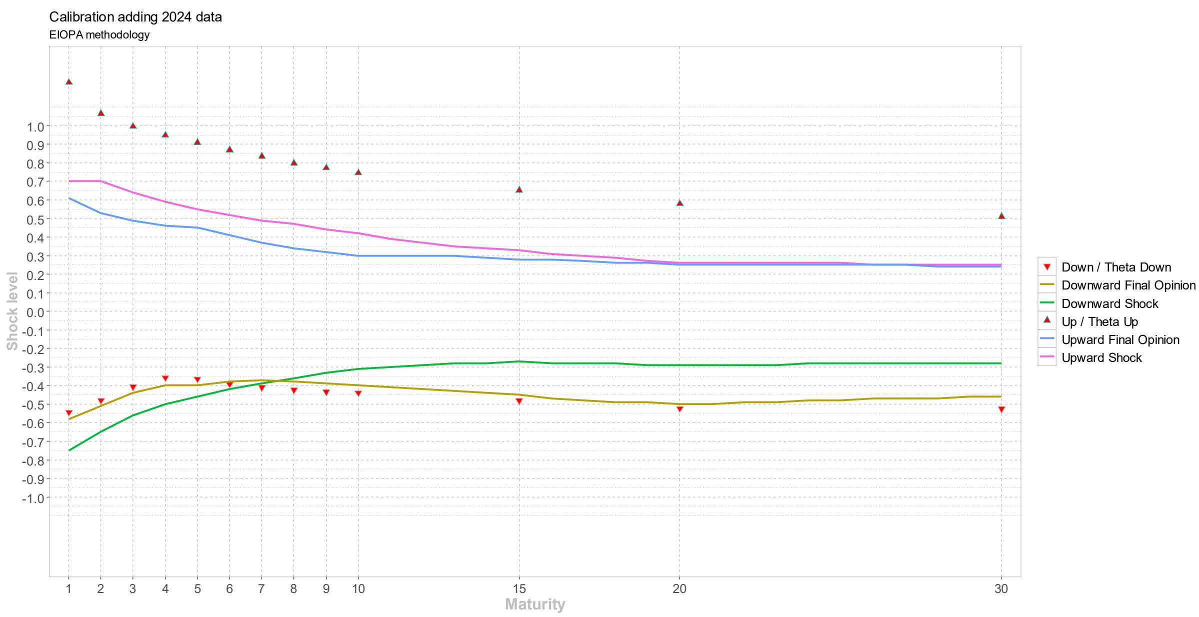

Chart 16. Update of EIOPA's shocks with data up to 2024

While the downward shocks seem relatively stable, the upward shocks are doubled (if not more). This result does not come as a surprise since the extended dataset includes violent interest rates increases.

The following shock parameters are estimated:

Maturity	s_{down}	b_{down}	s_{up}	b_{up}
1	54	1,09	123	4,32
2	48	0,91	106	3,72
3	41	0,75	100	3,48
4	36	0,64	95	3,32
5	36	0,64	91	3,18
6	39	0,67	87	3,04
7	41	0,68	83	2,92
8	42	0,68	80	2,80
9	43	0,67	77	2,70
10	44	0,66	75	2,61
15	48	0,6	65	2,28
20	52	0,52	58	2,03
30	53	0,53	51	1,78

Review of parameters with controlled inflation

- **Attempting to neutralize part of interest rate volatility through inflation control**

Two slightly different approaches were tested:

- Interest rates are diminished by the inflation at observation date,
- Inflation is not deducted from interest rates however, it is capped when above ECB target.

In this last configuration, the following parameters were calibrated:

Maturity	s_{down}	b_{down}	s_{up}	b_{up}
1	-63	-3,76	89	10,28
2	-51	-1,53	75	5,65
3	-37	-0,74	56	3,94
4	-32	-0,65	49	3,16
5	-34	-0,68	46	2,75
6	-36	-0,71	44	2,63
7	-37	-0,74	42	2,55
8	-37	-0,75	41	2,46
9	-38	-0,76	39	2,36
10	-38	-0,76	38	2,30
15	-38	-0,76	34	2,05
20	-38	-0,75	30	1,82
30	-38	-0,76	27	1,63

In this specific calibration, multiplicative shock parameters are relatively contained. However, this comes at the cost of an additive shock significantly higher than EIOPA's proposed shock.

- **A closer look at the data: 2019-2022 conundrum**

Plotting nominal rates against real ones shows the singularity of the period between 2019 and 2022[14]. While data before 2019 show an expected (approximately) linear pattern, data between 2019 and 2022 demonstrate that evolution of nominal and real rates has been disconnected. Most recent data may show a return to previous behavior, while it may be too soon to convey a definitive conclusion.

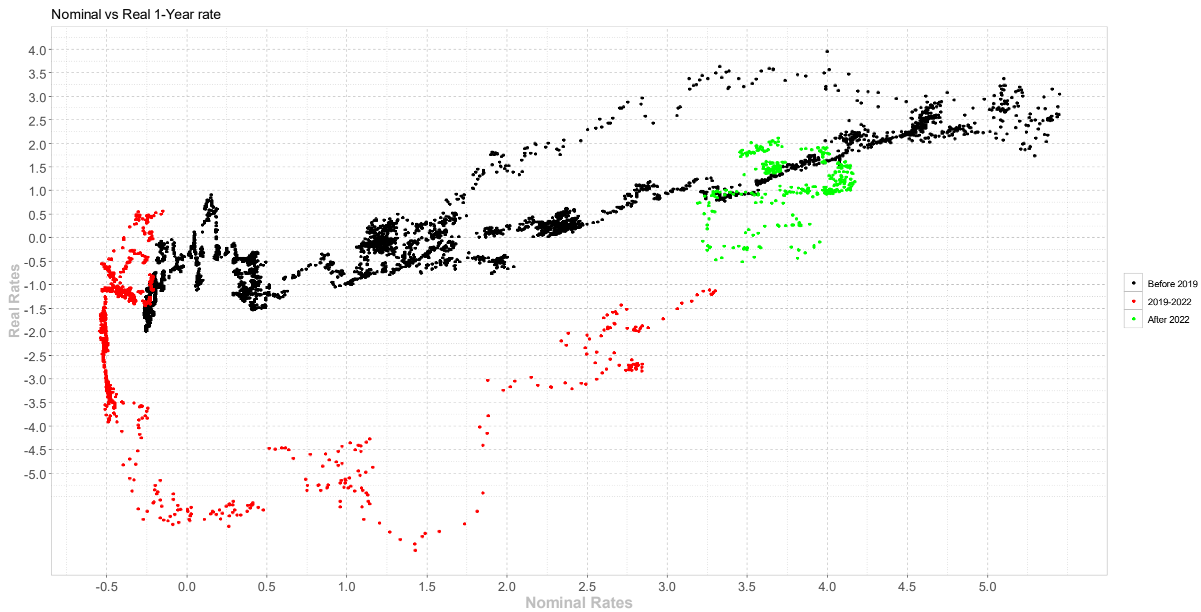

Chart 17. 1-year nominal rates against 1-year real rates

This regime change in data between 2019 and 2022 helps explain why attempts to smooth interest rate volatility through inflation control have not proven as efficient as expected.

A failed shift from multiplicative to additive shocks

In an attempt to provide a sound calibration, changes in interest rates have been computed in absolute terms in state of relative terms. Thereafter, the same methodology to derive quantiles has been applied.

[14] Time span bounds could be refined with statistical analysis.

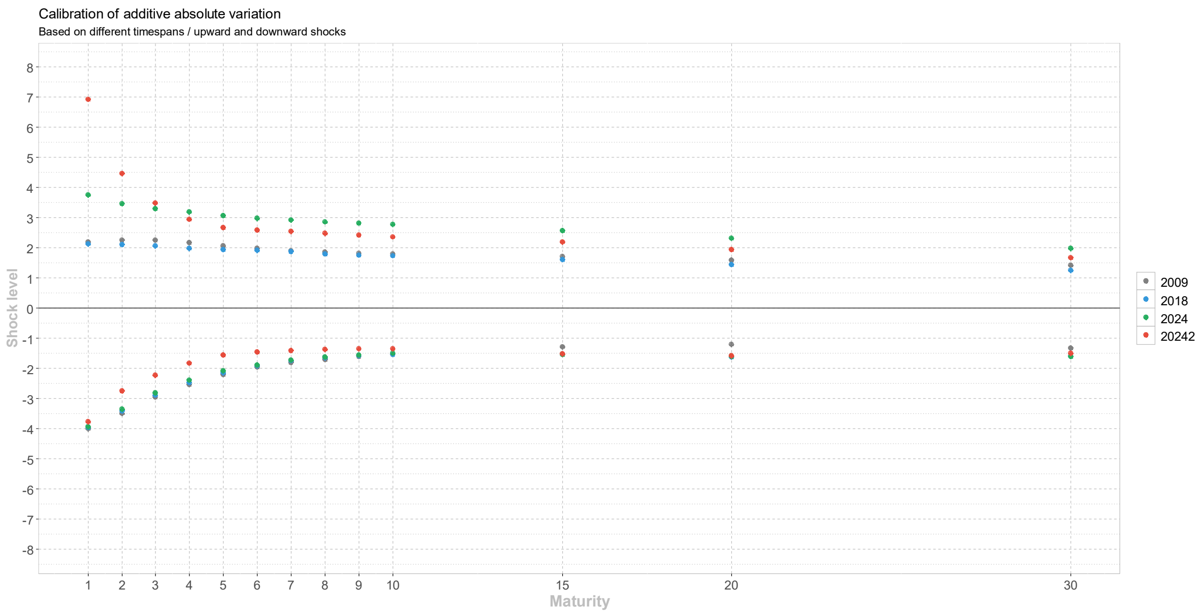

Chart 18. Calibration of additive shocks based on absolute rate changes

The two possibilities tested (2024 and 20242, corresponding to data up to 2024 and data up to 2024 with a cap on inflation) show an unrealistic increase to the shocks at least for maturities before 10 years.

Appendix 4. Proposal back-testing

The proposal is applied in different real-life conditions to illustrate how shocks would have been shocked.

In 2019, the left panel shows that no downward shock is applied under current framework, a shortfall already identified in 2018. Application of the inflation corridor has no effect and leads to a shock similar to final opinion's shock. On the right panel, EIOPA's methodology is applied on data extended to include 2024 figures (i.e. an actualized version of the final opinion) and it is compared to the quantile regression approach presented in this document. The corridor inflation tool is not activated.

Actualization of final opinion with 2024 data to an upward shock 150 bps higher than EIOPA's final opinion. However, those EIOPA's actualized shocks are in the same severity range as the quantile regression from this document.

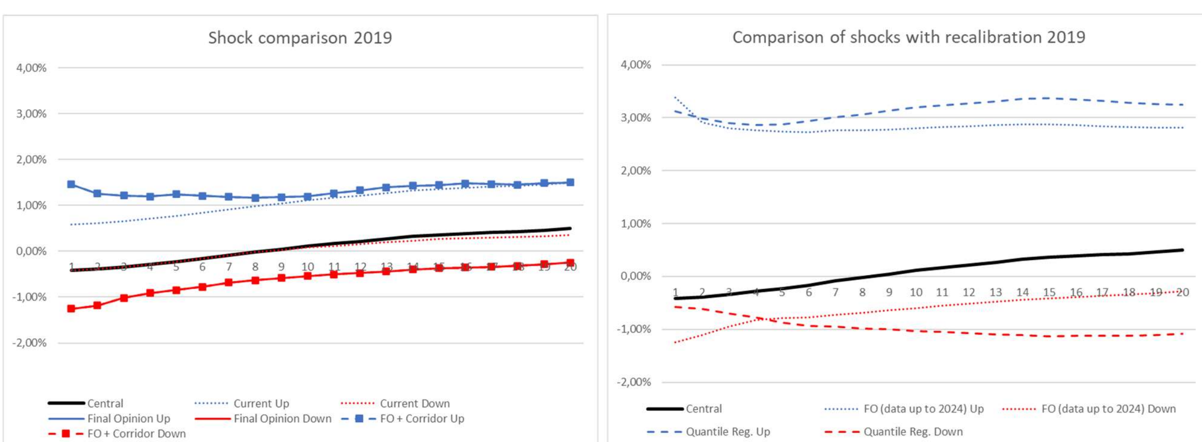

Chart 19. Test of inflation corridor and quantile regression in 2019

In 2020, the left panel displays an upward shock more severe with final opinion shocks, inflation corridor is not used. Actualization of final opinion with 2024 data to an upward shock 150 to 200 bps higher than final opinion.

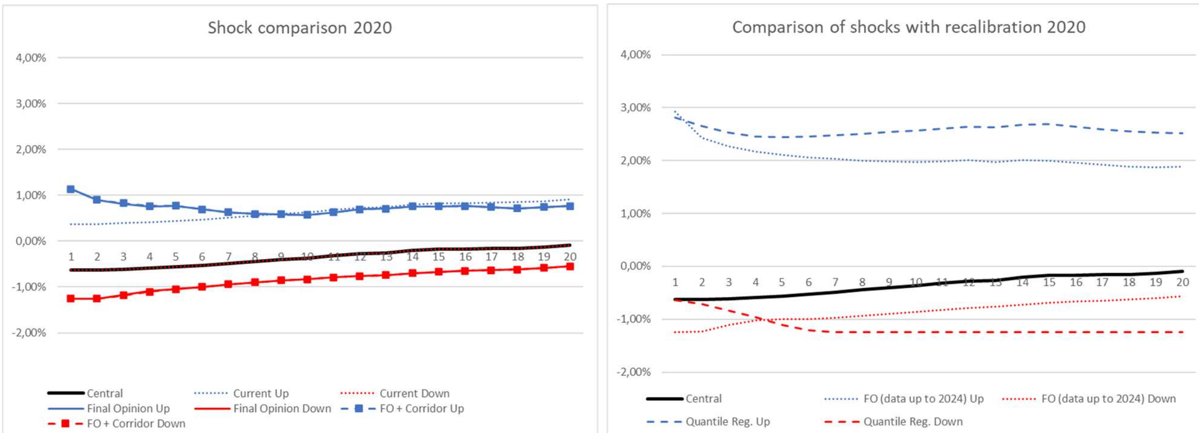

Chart 20. Test of inflation corridor and quantile regression in 2020

In 2022, the left panel of the chart depicts application of the inflation corridor and its effect in reducing shocks (w.r.t. final opinion's shocks) for the shortest maturities both upward and downward. On the right panel, EIOPA's methodology is applied on data extended to include 2024 leading to an increase of 600 bps in the shocks for shortest maturities.

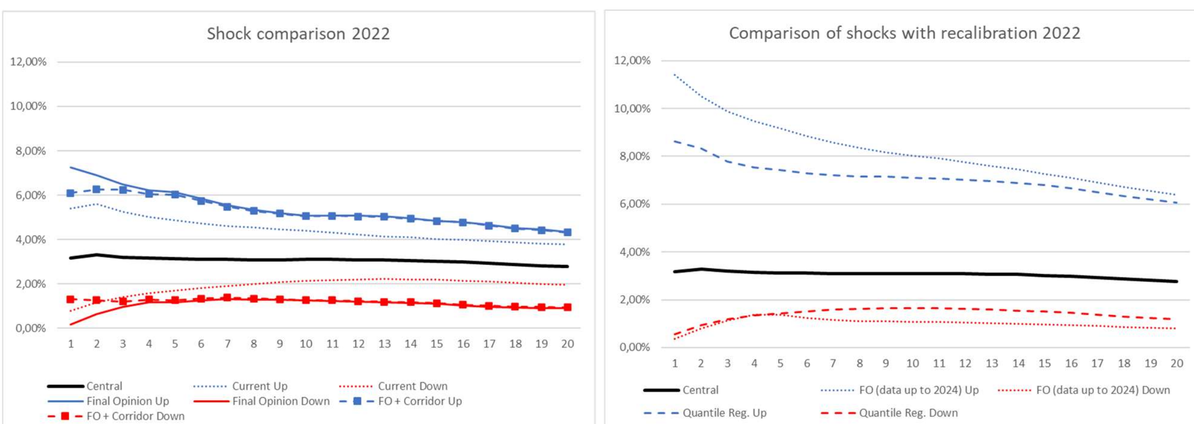

Chart 21. Test of inflation corridor and quantile regression in 2022