

Valutare la resilienza dell'industria assicurativa Europea nel quadro di Solvency II: dal Solvency Ratio al Resiliency Ratio

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The introduction of **Solvency II** as of 1 January 2016 has contributed to increase capital and reserving requirements of the insurers with the scope to make more robust the solvency of the European insurance companies. Under Solvency II:

- A market-consistent approach is adopted for the balance sheet to calculate the **Eligible Own Funds (EOF)**.
- A risk-sensitive capital requirement, the **Solvency Capital Requirement (SCR)**, is calculated as Value at Risk at 99.5% with a time horizon of one year
- The **Solvency Ratio (SR)**, is $SR = \frac{EOF}{SCR} \geq 100\%$

The market-consistent framework and the risk-based capital requirement allow to derive simplified tools in the form of **Early Warning Indicators (EWIs)** could help to anticipate potential issues affecting the capital position.

Proposed model: assumptions and definitions 1/3

Under the market-consistent approach featuring Solvency II, we assume that assets $A(t)$ and liabilities $L(t)$ follow a bivariate geometric Brownian motion (GBM) in order to model the **asset-liability ratio** $V(t) = \frac{A(t)}{L(t)}$,

$$\frac{dA(t)}{A(t)} = rdt + \sigma_A dW_A^{\mathbb{Q}}(t), \quad \frac{dL(t)}{L(t)} = rdt + \sigma_L dW_L^{\mathbb{Q}}(t),$$

where:

- r is the constant risk-free short-term interest rate
- σ_A and σ_L are the standard deviations related to asset and liability, respectively
- $\mathbb{Q}$ is the risk-adjusted (or risk-neutral) measure having the cash account as numeraire
- $dW_A^{\mathbb{Q}}(t)$ and $dW_L^{\mathbb{Q}}(t)$ are correlated standard Brownian motions such that

$$dW_A^{\mathbb{Q}}(t)dW_L^{\mathbb{Q}}(t) = \rho dt$$

- ρ is the instantaneous correlation coefficient.

By Itô's lemma, the ratio $V(t)$ is itself a geometric Brownian motion,

$$\frac{dV(t)}{V(t)} = (\sigma_L^2 - \rho\sigma_A\sigma_L)dt + \sigma_A dW_A^{\mathbb{Q}}(t) - \sigma_L dW_L^{\mathbb{Q}}(t).$$

By Girsanov's theorem, we introduce an equivalent probability measure $\mathbb{Q}'$ under which the ratio $V(t)$ has zero drift:

$$\frac{dV(t)}{V(t)} = \sigma_V dW_V^{\mathbb{Q}'}(t).$$

where $\mathbb{Q}'$ denotes the measure associated with the liability numeraire $L(t)$.

Following the structural credit model proposed by Merton (1974), the probability that the company defaults at time T is

$$PD(t_0, T) = \mathbb{P}_{t_0}[A(T) < L(T)].$$

The terminal equity payoff is given by

$$E(T) = \max[A(T) - L(T), 0].$$

The value of equity can be viewed as the value of an exchange (or spread) option i.e the option to exchanges one risky asset for another risky asset at maturity.

Applying Margrabe's formula (1978), we obtain

$$E(t_0) = e^{-r(T-t_0)} \mathbb{E}^{\mathbb{Q}} [(A(T) - L(T))^+ | \mathcal{F}_{t_0}] = L(t_0) \mathbb{E}^{\mathbb{Q}'} \left[\left(\frac{A(T)}{L(T)} - 1 \right)^+ \middle| \mathcal{F}_{t_0} \right],$$

The equity is a vanilla call option on the underlying asset-liability ratio $V(t_0)$, with strike price equal to 1, zero interest rate and volatility σ_V .

The value of equity is therefore given by

$$E(t_0) = A(t_0)\Phi(d_1) - L(t_0)\Phi(d_2),$$

where

$$d_{1,2} = \frac{\ln \left[\frac{A(t_0)}{L(t_0)} \right] \pm \frac{1}{2} \sigma_V^2 (T - t_0)}{\sigma_V \sqrt{(T - t_0)}},$$

Consequently, the probability of default can be calculated in closed-form as follows,

$$PD(t_0, T) = \mathbb{P}_{t_0} [A(T) < L(T)] = \mathbb{P}_{t_0} [V(T) < 1] = \Phi(-d_2),$$

where Φ is the cumulative distribution function of the standard normal distribution.

Calibrating the Model: Implied Volatility of the Asset–Liability Ratio (1/2)

The model can be calibrated using point-in-time data reported under the Solvency II framework.

Publicly available Solvency II data provide all the information required for calibration.

Calibration assumption:

We keep the SCR fixed and allow the EOF to vary. Consequently, the solvency ratio changes accordingly:

$$SR^{\alpha}(t_0) = \frac{EOF^{\alpha}(t_0)}{SCR(t_0)}.$$

At the calibration point, we impose

$$SR^{\alpha}(t_0) = 100\% \quad \Longleftrightarrow \quad EOF^{\alpha}(t_0) = SCR(t_0).$$

Under this normalization, the probability of default over the horizon T is

$$\begin{aligned} PD^{\alpha}(t_0, T) &= \mathbb{P}[A^{\alpha}(T) < L(T)] \\ &= \Phi(-d_2^{\alpha}) = 1 - \alpha = 0.5\%. \end{aligned}$$

Moreover,

$$A^{\alpha}(t_0) = L(t_0) + EOF^{\alpha}(t_0) = L(t_0) + SCR(t_0).$$

Imposing

$$\Phi \left(- \frac{\ln \left[\frac{A^\alpha(t_0)}{L(t_0)} \right] - \frac{1}{2} \sigma_V^2 (T - t_0)}{\sigma_V \sqrt{(T - t_0)}} \right) = 0.5\%.$$

where $q_{1-\alpha}$ denotes the $1 - \alpha$ -quantile; in particular, $q_{0.005}$ is the 0.5th percentile.

This allow to obtain a closed-form solution for the **Implied Volatility (IV) of the asset-liability ratio** denoted by $\hat{\sigma}_V$,

$$\hat{\sigma}_V = \frac{1}{\sqrt{T - t_0}} \left[q_{0.005} + \sqrt{q_{0.005}^2 + 2 \log \left(1 + \frac{SCR(t_0)}{L(t_0)} \right)} \right].$$

The advantage of this approach is that we can perform the calibration of σ_V using only $L(t_0)$ and $SCR(t_0)$ as input data available under the Solvency II public disclosures. The disadvantage is that no inference can be done with respect to σ_A , σ_L and ρ .

Alternatively, historical volatilities and correlation computed from historical data can be used in place of the overall Implied Volatility.

Let now consider the actual figures of $A(t_0)$ and $L(t_0)$.

Probability of Default: As introduced above, the probability of default at time T is

$$PD(t_0, T) = \mathbb{P}_{t_0}[A(T) < L(T)] = \Phi(-d_2).$$

First-passage Probability of Default: Moreover we can also compute the first-passage default probability before T (Black-Cox) defining the default time

$$\tau = \inf \{s \geq t_0 : V(s) \leq 1\}, \quad V(t_0) > 1.$$

The probability that $V(s)$ first falls below (1) before time (T) can be calculated in closed form as follows:

$$\mathbb{P}_{\text{hit}}(t_0 \leq \tau \leq T) = \Phi\left(\frac{-m(T - t_0) - b}{\sigma\sqrt{T - t_0}}\right) + \exp\left(-\frac{2mb}{\sigma^2}\right) \Phi\left(\frac{m(T - t_0) - b}{\sigma\sqrt{T - t_0}}\right),$$

where

$$m = -\frac{1}{2}\sigma_V^2, \quad b = \ln(V(t_0)).$$

Model output: Probability of Breaching SCR (1/2)

The probability, evaluated today at time t_0 , that the company breaches the SCR at time T is

$$PB(t_0, T) = \mathbb{P}_{t_0} [A(T) < L(T) + K].$$

where $K = SCR(t_0)$. Define the shifted process

$$S(t) = L(t) + K, \quad K \in \mathbb{R},$$

and the ratio

$$V^*(t) = \frac{A(t)}{S(t)}.$$

Using Itô's formula, the ratio process satisfies the SDE

$$\frac{dV^*(t)}{V^*(t)} = \left[r - r\lambda(t) - \rho\sigma_A\sigma_L\lambda(t) + \sigma_L^2\lambda(t)^2 \right] dt + \left[\sigma_A dW_A^Q(t) - \sigma_L\lambda(t) dW_L^Q(t) \right],$$

where

$$\lambda(t) = \frac{L(t)}{L(t) + K}.$$

The instantaneous variance of the ratio is

$$\sigma_{V^*}(t) = \sqrt{\sigma_A^2 + \sigma_L^2 \left(\frac{L(t)}{L(t) + K} \right)^2 - 2\rho\sigma_A\sigma_L \left(\frac{L(t)}{L(t) + K} \right)}.$$

$V^*(t)$ is not A GBM since both the drift and the volatility are stochastic.

- Kirk (1995) approximates $V^*(t)$ locally by a GBM with constant volatility $\sigma_{V_K^*}$, setting $\lambda(t) \approx \lambda(t_0) = \frac{L(t_0)}{L(t_0)+K}$.
- This approximation makes it possible to obtain a closed-form formula for the breach probability or for the spread option price.
- Under this approximation, the probability of default at time T admits the following closed-form representation under a pricing measure

$$\text{PB}(t_0, T) \approx \Phi \left(- \frac{\ln \left(\frac{A(t_0)}{L(t_0)+K} \right) - \frac{1}{2} \sigma_{V_K^*}^2 (T - t_0)}{\sigma_{V_K^*} \sqrt{T - t_0}} \right).$$

In our analysis we assume $\sigma_{V_K^*} \approx \sigma_V$ when $\frac{L(t_0)}{L(t_0)+K}$ is close to one.

Model output: First-Passage Probability of Breach the SCR

Under the Kirk approximation, $V^*(t)$ is approximated by a geometric Brownian motion with constant volatility $\sigma_{V_K^*}$, obtained by freezing the coefficients at time t_0 . Define the breach time as

$$\tau^* = \inf \{s \geq t_0 : V^*(s) \leq 1\}, \quad V^*(t_0) > 1.$$

The first-passage probability of breach SCR before time T is therefore

$$P_{\text{hit}}(t_0, T) = \mathbb{P} \left[\inf_{t_0 \leq s \leq T} V^*(s) \leq 1 \mid V^*(t_0) > 1 \right].$$

Consequently, the first-passage probability of breach SCR is

$$P_{\text{hit}}(t_0, T) = \Phi \left(\frac{-b - m(T - t_0)}{\sigma_{V_K^*} \sqrt{T - t_0}} \right) + \exp \left(-\frac{2mb}{\sigma_{V_K^*}^2} \right) \Phi \left(\frac{-b + m(T - t_0)}{\sigma_{V_K^*} \sqrt{T - t_0}} \right).$$

where

$$b = \ln(V^*(t_0)) = \ln \left(\frac{A(t_0)}{L(t_0) + K} \right), \quad m = -\frac{1}{2} \sigma_{V_K^*}^2.$$

We propose the **Resiliency Ratio (RR)** as a novel metric to evaluate the insurer's resilience.

Setting the asset-liability ratio (at time T) as a random variable,

$$V(T) = \frac{A(T)}{L(T)},$$

we calculate the expected value and variance of this random variable under the measure $\mathbb{Q}'$,

$$\mathbb{E}^{\mathbb{Q}'} \left[\frac{A(T)}{L(T)} \middle| \mathcal{F}_{t_0} \right] = \frac{A(t_0)}{L(t_0)} = V(t_0),$$

$$\mathbb{V}ar^{\mathbb{Q}'} \left[\frac{A(T)}{L(T)} \middle| \mathcal{F}_{t_0} \right] = \sigma_V^2.$$

In an intuitive manner and following the idea underlying the Coefficient of Variation used in statistics and the Sharpe Ratio (1966), we propose to calculate the resilience ratio (RR) as the reciprocal of the Coefficient of variation,

$$RR(t_0) = \frac{V(t_0)}{\sigma_V}.$$

An alternative and more effective formulation of the resilience ratio is

$$RR^*(t_0) = \frac{\log [A(t_0)/L(t_0)]}{\sigma_V^2}.$$

The meaning of the proposed economic resiliency ratio is twofold:

- (1) the higher is the value of the index, the higher is the ability of the insurer to be resilient in case of stressed scenarios,
- (2) given two insurance companies with the same solvency ratio, the company with the higher *RR* will result as more resilient than the other.

Beyond standard tools such as scenario analysis, sensitivity analysis and stress testing, the resilience ratio provides a compact and informative measure of an insurer's solvency position combined with its ability to withstand adverse market conditions.

A higher resilience ratio implies a lower volatility of the Solvency Ratio and a lower probability of solvency breach, whereas a lower resilience ratio indicates increased fragility.

EIOPA data available at aggregated level by countries

EIOPA provides statistical data on insurance undertakings and groups in the EU and the European Economic Area (EEA).

The statistics contain aggregated country level information about balance sheet, own funds, premiums, claims and expenses, asset exposures, use of transitional and LTG measures.

EIOPA data from YE17 to YE25 have been used to calibrate the model and providing the results at country level (Eur/mlin).

Data for the Solo entities (annual data, including LTG measures) have been used.

Specifically the following information has been considered by countries: MVA, MVL, ESF, and SCR

Data are public and available for downloading from EIOPA website:

<https://www.eiopa.europa.eu> -- > tools-and-data -- > insurance-statistics

Solvency Ratio, Resiliency Ratio and other metrics as of YE25 (1/5)

Country	MVA	MVL	EOF	SCR	SR	ImpVol	PD	PB	RR
FRANCE	3.146.353	2.625.863	520.491	207.846	250%	2,9%	4,26E-10	0,0197%	209,1
GERMANY	2.514.244	1.917.861	596.384	195.217	305%	3,7%	2,44E-13	0,0002%	194,0
ITALY	1.149.248	979.882	169.366	61.990	273%	2,4%	9,49E-12	0,0018%	283,7
DENMARK	651.454	608.605	42.849	17.434	246%	1,1%	2,60E-10	0,0141%	568,4
IRELAND	547.018	496.223	50.796	28.409	179%	2,2%	3,13E-06	2,6757%	210,4
NETHERLANDS	460.769	392.915	67.854	34.097	199%	3,2%	3,80E-07	0,9296%	154,5
SWEDEN	459.838	367.421	92.417	52.071	177%	5,1%	5,98E-06	3,7794%	86,4
BELGIUM	363.410	309.514	53.896	25.738	209%	3,1%	1,04E-07	0,4651%	168,9
SPAIN	340.228	276.574	63.654	26.823	237%	3,6%	3,60E-09	0,0705%	162,6
LUXEMBOURG	310.097	269.995	40.102	18.174	221%	2,5%	2,01E-08	0,1858%	218,6
NORWAY	251.216	225.010	26.206	11.143	235%	1,9%	2,01E-09	0,0487%	315,2
AUSTRIA	139.162	87.879	51.284	16.583	309%	6,6%	2,51E-12	0,0009%	104,7
FINLAND	95.485	78.766	16.719	7.137	234%	3,3%	4,83E-09	0,0833%	172,0
PORTUGAL	59.418	51.087	8.330	3.915	213%	2,9%	6,30E-08	0,3526%	185,9
POLAND	57.284	36.543	20.741	8.918	233%	8,3%	4,48E-08	0,3174%	64,6
LIECHTENSTEIN	28.610	24.782	3.828	1.992	192%	3,0%	8,02E-07	1,3651%	161,3
GREECE	22.092	18.128	3.964	2.287	173%	4,6%	8,49E-06	4,4328%	94,6
CZECH REPUBLIC	19.747	14.549	5.198	2.522	206%	6,1%	3,69E-07	0,9526%	81,2
MALTA	17.611	9.952	7.659	3.002	255%	10,0%	8,78E-09	0,1314%	56,6
HUNGARY	12.282	9.795	2.487	1.266	196%	4,7%	7,37E-07	1,3365%	103,5
SLOVENIA	10.918	7.201	3.717	1.471	253%	7,1%	3,10E-09	0,0688%	82,1
ROMANIA	8.396	6.205	2.192	1.335	164%	7,5%	2,92E-05	7,9870%	54,4
CROATIA	6.520	4.319	2.201	922	239%	7,4%	1,64E-08	0,1790%	75,1
BULGARIA	6.487	4.143	2.344	1.307	179%	10,4%	1,09E-05	5,2960%	41,2
SLOVAKIA	6.106	4.786	1.319	726	182%	5,4%	4,09E-06	3,1614%	82,7
CYPRUS	5.783	4.042	1.741	621	280%	5,5%	4,23E-11	0,0050%	118,7
ESTONIA	2.828	2.041	787	465	169%	7,8%	1,89E-05	6,6126%	53,0
LITHUANIA	2.202	1.581	621	364	171%	7,9%	1,70E-05	6,3018%	52,9
LATVIA	1.828	1.469	359	246	146%	5,9%	1,30E-04	14,7831%	62,0
ICELAND	1.700	1.148	552	381	145%	10,9%	1,92E-04	17,8511%	33,1
EEA	10.698.336	8.838.281	1.860.055	734.403	253%	3,1%	3,11E-10	0,0163%	201,3

Figure 1: Own elaboration on EIOPA data YE25 (€/mln): ordered by MVA

Solvency Ratio, Resiliency Ratio and other metrics as of YE25 (2/5)

Country	MVA	MVL	EOF	SCR	SR	ImpVol	PD	PB	RR
AUSTRIA	139.162	87.879	51.284	16.583	309%	6,6%	2,51E-12	0,0009%	104,7
GERMANY	2.514.244	1.917.861	596.384	195.217	305%	3,7%	2,44E-13	0,0002%	194,0
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Figure 2: Own elaboration on EIOPA data YE25 (€/mln): ordered by SR

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LIECHTENSTEIN	28.610	24.782	3.828	1.992	192%	3,0%	8,02E-07	1,3651%	161,3
FRANCE	3.146.353	2.625.863	520.491	207.846	250%	2,9%	4,26E-10	0,0197%	209,1
PORTUGAL	59.418	51.087	8.330	3.915	213%	2,9%	6,30E-08	0,3526%	185,9
LUXEMBOURG	310.097	269.995	40.102	18.174	221%	2,5%	2,01E-08	0,1858%	218,6
ITALY	1.149.248	979.882	169.366	61.990	273%	2,4%	9,49E-12	0,0018%	283,7
IRELAND	547.018	496.223	50.796	28.409	179%	2,2%	3,13E-06	2,6757%	210,4
NORWAY	251.216	225.010	26.206	11.143	235%	1,9%	2,01E-09	0,0487%	315,2
DENMARK	651.454	608.605	42.849	17.434	246%	1,1%	2,60E-10	0,0141%	568,4
EEA	10.698.336	8.838.281	1.860.055	734.403	253%	3,1%	3,11E-10	0,0163%	201,3

Figure 3: Own elaboration on EIOPA data YE25 (€/mln): ordered by ImpVol

Solvency Ratio, Resiliency Ratio and other metrics as of YE25 (4/5)

Country	MVA	MVL	EOF	SCR	SR	ImpVol	PD	PB	RR
ICELAND	1.700	1.148	552	381	145%	10,9%	1,92E-04	17,8511%	33,1
LATVIA	1.828	1.469	359	246	146%	5,9%	1,30E-04	14,7831%	62,0
ROMANIA	8.396	6.205	2.192	1.335	164%	7,5%	2,92E-05	7,9870%	54,4
ESTONIA	2.828	2.041	787	465	169%	7,8%	1,89E-05	6,6126%	53,0
LITHUANIA	2.202	1.581	621	364	171%	7,9%	1,70E-05	6,3018%	52,9
BULGARIA	6.487	4.143	2.344	1.307	179%	10,4%	1,09E-05	5,2960%	41,2
GREECE	22.092	18.128	3.964	2.287	173%	4,6%	8,49E-06	4,4328%	94,6
SWEDEN	459.838	367.421	92.417	52.071	177%	5,1%	5,98E-06	3,7794%	86,4
SLOVAKIA	6.106	4.786	1.319	726	182%	5,4%	4,09E-06	3,1614%	82,7
IRELAND	547.018	496.223	50.796	28.409	179%	2,2%	3,13E-06	2,6757%	210,4
LIECHTENSTEIN	28.610	24.782	3.828	1.992	192%	3,0%	8,02E-07	1,3651%	161,3
HUNGARY	12.282	9.795	2.487	1.266	196%	4,7%	7,37E-07	1,3365%	103,5
CZECH REPUBLIC	19.747	14.549	5.198	2.522	206%	6,1%	3,69E-07	0,9526%	81,2
NETHERLANDS	460.769	392.915	67.854	34.097	199%	3,2%	3,80E-07	0,9296%	154,5
BELGIUM	363.410	309.514	53.896	25.738	209%	3,1%	1,04E-07	0,4651%	168,9
PORTUGAL	59.418	51.087	8.330	3.915	213%	2,9%	6,30E-08	0,3526%	185,9
POLAND	57.284	36.543	20.741	8.918	233%	8,3%	4,48E-08	0,3174%	64,6
LUXEMBOURG	310.097	269.995	40.102	18.174	221%	2,5%	2,01E-08	0,1858%	218,6
CROATIA	6.520	4.319	2.201	922	239%	7,4%	1,64E-08	0,1790%	75,1
MALTA	17.611	9.952	7.659	3.002	255%	10,0%	8,78E-09	0,1314%	56,6
FINLAND	95.485	78.766	16.719	7.137	234%	3,3%	4,83E-09	0,0833%	172,0
SPAIN	340.228	276.574	63.654	26.823	237%	3,6%	3,60E-09	0,0705%	162,6
SLOVENIA	10.918	7.201	3.717	1.471	253%	7,1%	3,10E-09	0,0688%	82,1
NORWAY	251.216	225.010	26.206	11.143	235%	1,9%	2,01E-09	0,0487%	315,2
FRANCE	3.146.353	2.625.863	520.491	207.846	250%	2,9%	4,26E-10	0,0197%	209,1
DENMARK	651.454	608.605	42.849	17.434	246%	1,1%	2,60E-10	0,0141%	568,4
CYPRUS	5.783	4.042	1.741	621	280%	5,5%	4,23E-11	0,0050%	118,7
ITALY	1.149.248	979.882	169.366	61.990	273%	2,4%	9,49E-12	0,0018%	283,7
AUSTRIA	139.162	87.879	51.284	16.583	309%	6,6%	2,51E-12	0,0009%	104,7
GERMANY	2.514.244	1.917.861	596.384	195.217	305%	3,7%	2,44E-13	0,0002%	194,0
EEA	10.698.336	8.838.281	1.860.055	734.403	253%	3,1%	3,11E-10	0,0163%	201,3

Figure 4: Own elaboration on EIOPA data YE25 (€/mln): ordered by PB

Solvency Ratio, Resiliency Ratio and other metrics as of YE25 (5/5)

Country	MVA	MVL	EOF	SCR	SR	ImpVol	PD	PB	RR
DENMARK	651.454	608.605	42.849	17.434	246%	1,1%	2,60E-10	0,0141%	568,4
NORWAY	251.216	225.010	26.206	11.143	235%	1,9%	2,01E-09	0,0487%	315,2
ITALY	1.149.248	979.882	169.366	61.990	273%	2,4%	9,49E-12	0,0018%	283,7
LUXEMBOURG	310.097	269.995	40.102	18.174	221%	2,5%	2,01E-08	0,1858%	218,6
IRELAND	547.018	496.223	50.796	28.409	179%	2,2%	3,13E-06	2,6757%	210,4
FRANCE	3.146.353	2.625.863	520.491	207.846	250%	2,9%	4,26E-10	0,0197%	209,1
GERMANY	2.514.244	1.917.861	596.384	195.217	305%	3,7%	2,44E-13	0,0002%	194,0
PORTUGAL	59.418	51.087	8.330	3.915	213%	2,9%	6,30E-08	0,3526%	185,9
FINLAND	95.485	78.766	16.719	7.137	234%	3,3%	4,83E-09	0,0833%	172,0
BELGIUM	363.410	309.514	53.896	25.738	209%	3,1%	1,04E-07	0,4651%	168,9
SPAIN	340.228	276.574	63.654	26.823	237%	3,6%	3,60E-09	0,0705%	162,6
LIECHTENSTEIN	28.610	24.782	3.828	1.992	192%	3,0%	8,02E-07	1,3651%	161,3
NETHERLANDS	460.769	392.915	67.854	34.097	199%	3,2%	3,80E-07	0,9296%	154,5
CYPRUS	5.783	4.042	1.741	621	280%	5,5%	4,23E-11	0,0050%	118,7
AUSTRIA	139.162	87.879	51.284	16.583	309%	6,6%	2,51E-12	0,0009%	104,7
HUNGARY	12.282	9.795	2.487	1.266	196%	4,7%	7,37E-07	1,3365%	103,5
GREECE	22.092	18.128	3.964	2.287	173%	4,6%	8,49E-06	4,4328%	94,6
SWEDEN	459.838	367.421	92.417	52.071	177%	5,1%	5,98E-06	3,7794%	86,4
SLOVAKIA	6.106	4.786	1.319	726	182%	5,4%	4,09E-06	3,1614%	82,7
SLOVENIA	10.918	7.201	3.717	1.471	253%	7,1%	3,10E-09	0,0688%	82,1
CZECH REPUBLIC	19.747	14.549	5.198	2.522	206%	6,1%	3,69E-07	0,9526%	81,2
CROATIA	6.520	4.319	2.201	922	239%	7,4%	1,64E-08	0,1790%	75,1
POLAND	57.284	36.543	20.741	8.918	233%	8,3%	4,48E-08	0,3174%	64,6
LATVIA	1.828	1.469	359	246	146%	5,9%	1,30E-04	14,7831%	62,0
MALTA	17.611	9.952	7.659	3.002	255%	10,0%	8,78E-09	0,1314%	56,6
ROMANIA	8.396	6.205	2.192	1.335	164%	7,5%	2,92E-05	7,9870%	54,4
ESTONIA	2.828	2.041	787	465	169%	7,8%	1,89E-05	6,6126%	53,0
LITHUANIA	2.202	1.581	621	364	171%	7,9%	1,70E-05	6,3018%	52,9
BULGARIA	6.487	4.143	2.344	1.307	179%	10,4%	1,09E-05	5,2960%	41,2
ICELAND	1.700	1.148	552	381	145%	10,9%	1,92E-04	17,8511%	33,1
EEA	10.698.336	8.838.281	1.860.055	734.403	253%	3,1%	3,11E-10	0,0163%	201,3

Figure 5: Own elaboration on EIOPA data YE25 (€/mln): ordered by RR

Solo entities by Country

Number of entities

Country	2017	2018	2019	2020	2021	2022	2023	2024	2025
Austria	37	35	35	34	33	33	32	32	31
Belgium	65	66	65	61	61	60	58	58	64
Denmark	84	78	77	76	74	71	70	68	65
France	476	468	459	457	455	449	440	443	444
Germany	339	338	336	333	333	331	334	328	323
Ireland	192	187	188	179	184	183	174	169	165
Italy	98	96	97	95	90	88	84	83	80
Luxembourg	272	268	270	263	255	260	259	257	260
Netherlands	140	132	124	120	114	113	110	110	108
Norway	72	70	68	66	61	63	60	59	57
Spain	160	152	147	148	150	151	140	136	131
Sweden	137	134	127	123	120	117	116	117	119
All	2584	2527	2482	2433	2401	2382	2337	2316	2294

Internal Model entities (%)

Country	2017	2018	2019	2020	2021	2022	2023	2024	2025
Austria	16	23	26	26	27	27	28	28	26
Belgium	8	9	11	10	11	12	12	12	11
Denmark	13	14	12	12	11	10	6	4	5
France	4	4	4	4	4	4	4	4	4
Germany	11	11	10	11	11	12	12	13	13
Ireland	7	7	7	7	7	8	8	8	8
Italy	14	15	14	15	16	16	17	17	16
Luxembourg	1	1	2	2	2	2	2	2	2
Netherlands	7	10	8	8	8	8	8	8	9
Norway	0	0	4	5	5	5	5	5	5
Spain	2	2	3	3	3	3	3	3	3
Sweden	4	4	4	4	4	4	4	4	4
All	5	6	6	6	6	6	6	6	6

SCR under internal model, percentage (%)

Country	2017	2018	2019	2020	2021	2022	2023	2024	2025
Austria	43	59	72	73	74	72	71	71	71
Belgium	34	29	31	28	31	30	30	31	24
Denmark	47	52	47	45	43	49	9	8	8
France	24	23	21	21	19	16	16	28	26
Germany	50	51	54	57	57	57	58	56	55
Ireland	34	37	33	34	29	31	37	35	34
Italy	69	66	67	65	64	61	66	67	68
Luxembourg	10	10	17	16	17	15	22	20	22
Netherlands	26	41	40	42	40	37	37	36	41
Norway	0	0	10	10	10	10	11	10	11
Spain	13	13	17	17	17	17	19	19	18
Sweden	13	13	12	13	14	12	12	11	11
All	34	36	37	38	36	35	35	37	36

Figure 6: Own elaboration on EIOPA data YE25

Solvency Ratio vs Resiliency Ratio as of YE25 - All entities

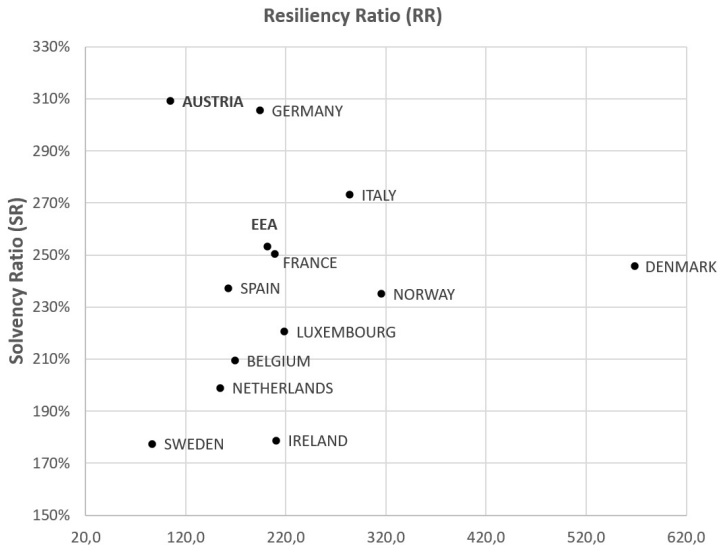


Figure 7: Own elaboration on EIOPA data YE25

Solvency Ratio vs Resiliency Ratio as of YE25 - Standard Formula entities

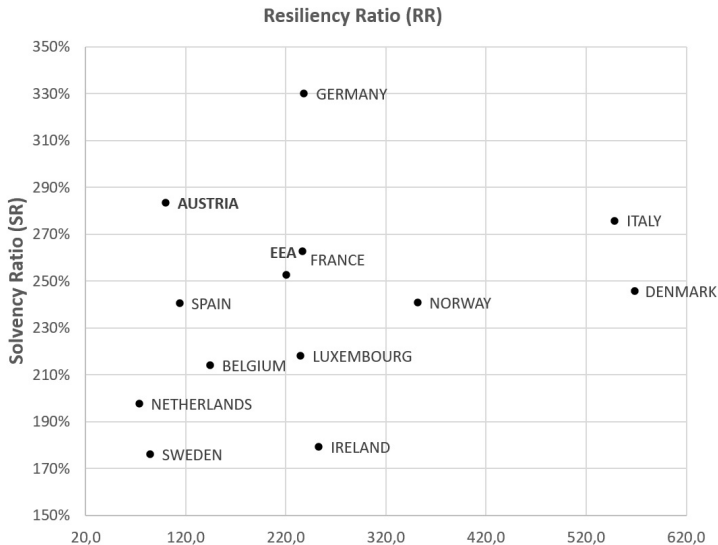


Figure 8: Own elaboration on EIOPA data YE25

Solvency Ratio vs Resiliency Ratio as of YE25 - Internal Model entities

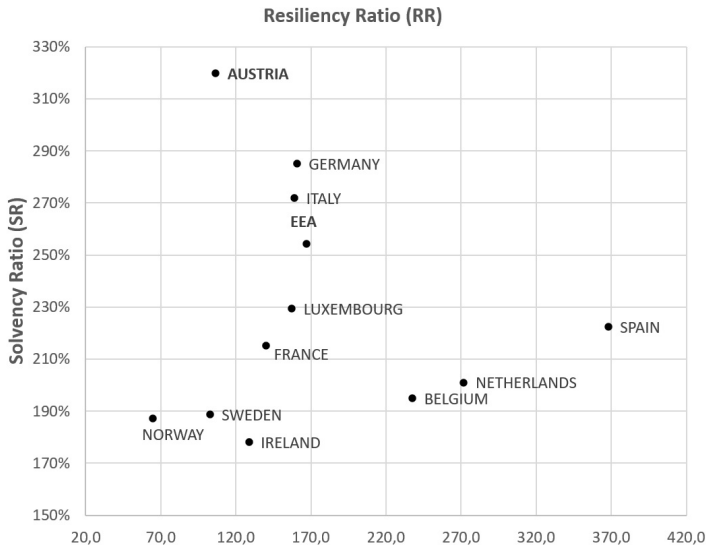


Figure 9: Own elaboration on EIOPA data YE25

Implied Volatility vs Historical Volatility: All entities

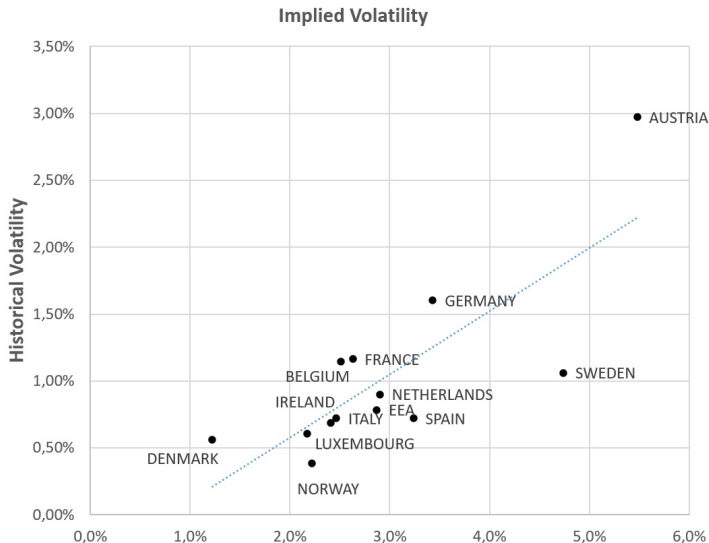


Figure 10: Own elaboration on EIOPA data YE17 - YE25

Solvency Ratio

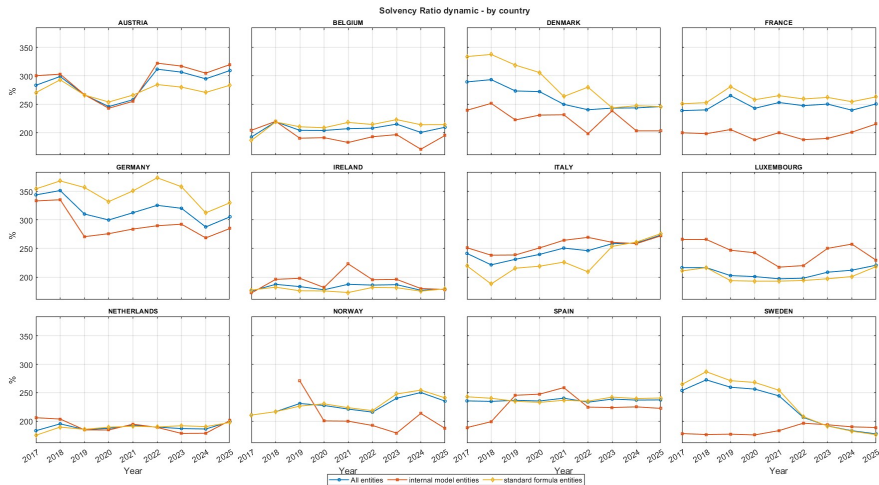


Figure 11: Own elaboration on EIOPA data YE17 - YE25

Probability of a breach of the SCR in T - Implied Volatility

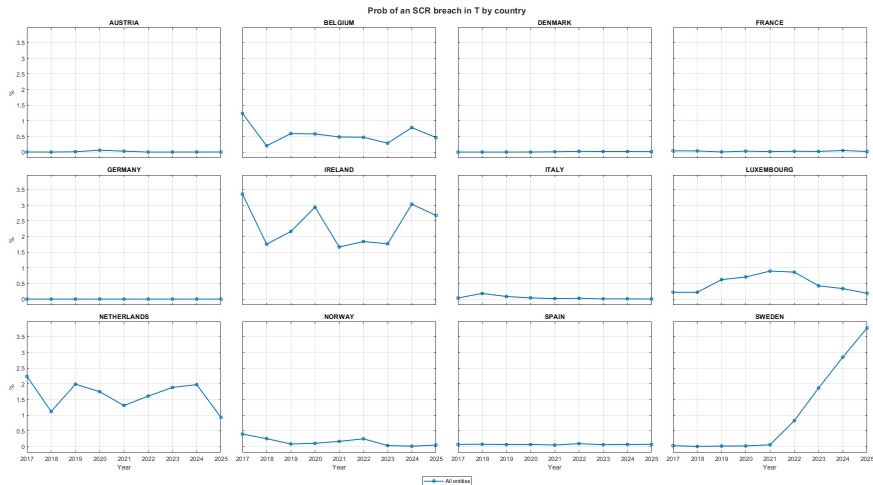


Figure 12: Own elaboration on EIOPA data YE17 - YE25

Probability of a breach of the SCR before T - Implied Volatility

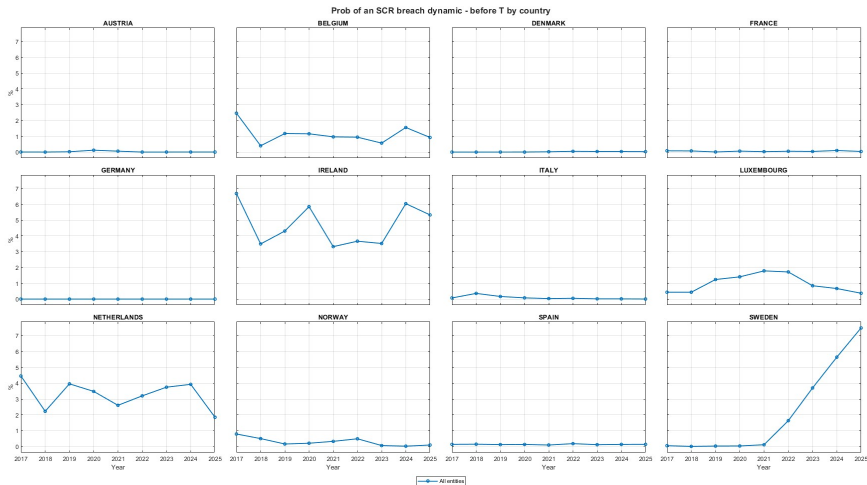


Figure 13: Own elaboration on EIOPA data YE17 - YE25

Resilience Ratio

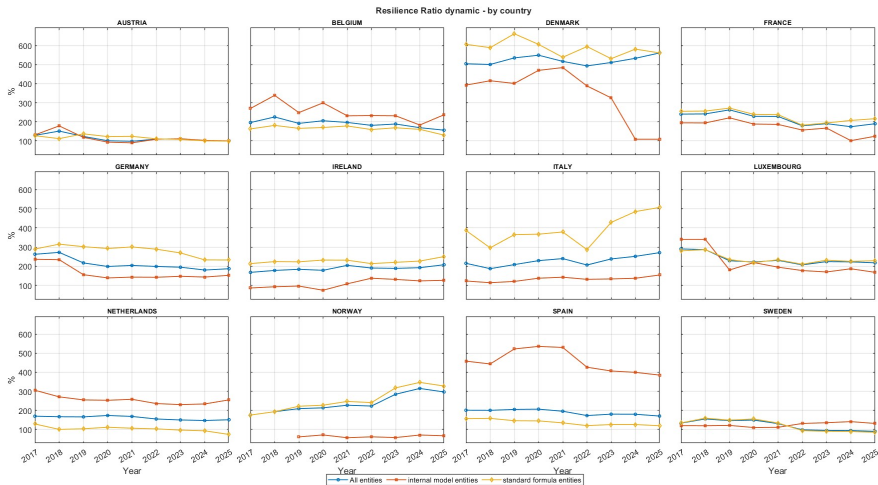


Figure 14: Own elaboration on EIOPA data YE17 - YE25

- **Main takeaways:**

- The proposed approach may be useful for inferring latent information embedded in Solvency II data.
- Such information may provide useful early warning indicators, complementing the official information disclosed under Solvency II.

- **However:**

- These indicators should be interpreted with caution, given their strong dependence on the underlying assumptions.
- The main set of assumptions is the one underlying the Merton-Margrabe-Kirk's framework where assets and liabilities are assumed to follow GBMs.
- While this framework has the advantage of analytical tractability, it could not be fully suitable for estimating risk.
- Furthermore, Implied Volatility and, consequently, also the other metrics like Resiliency Ratio, is sensitive to the SCR calculation methodology and risk assumptions embedded therein.
- In particular, Implied Volatility and the other derived metrics also strongly depends by the asset allocation and by the volatility of such assets assumed within the SCR calculation environment.
- The proposed indicators are not intended, in any way, to replace stress testing or sensitivity analyses, which typically rely on a full bottom-up approach.

Some references are:

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Disclaimer: The views expressed in this presentation are solely those of Vincenzo Russo and do not necessarily reflect the views, opinions, or position of his employer.

Annex: Probability of a breach of the SCR in T - Historical Volatility

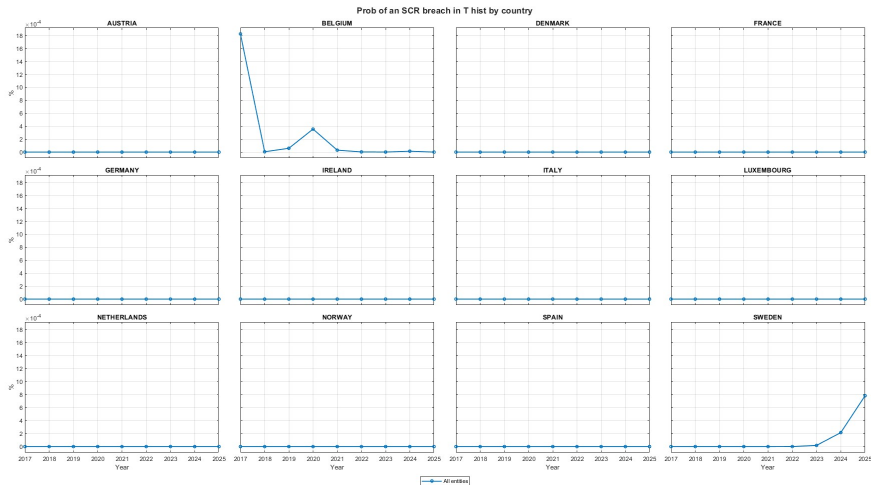


Figure 15: Own elaboration on EIOPA data YE17 - YE25

Annex: Probability of a breach of the SCR before T - Historical Volatility

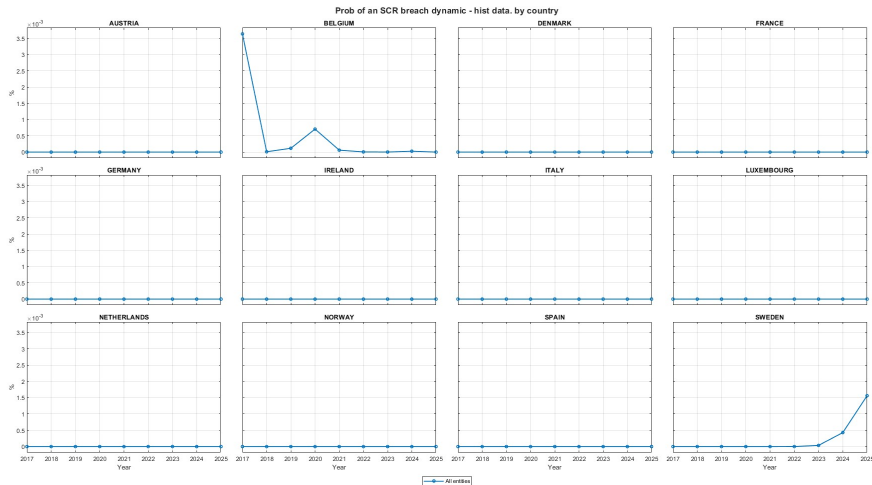


Figure 16: Own elaboration on EIOPA data YE17 - YE25