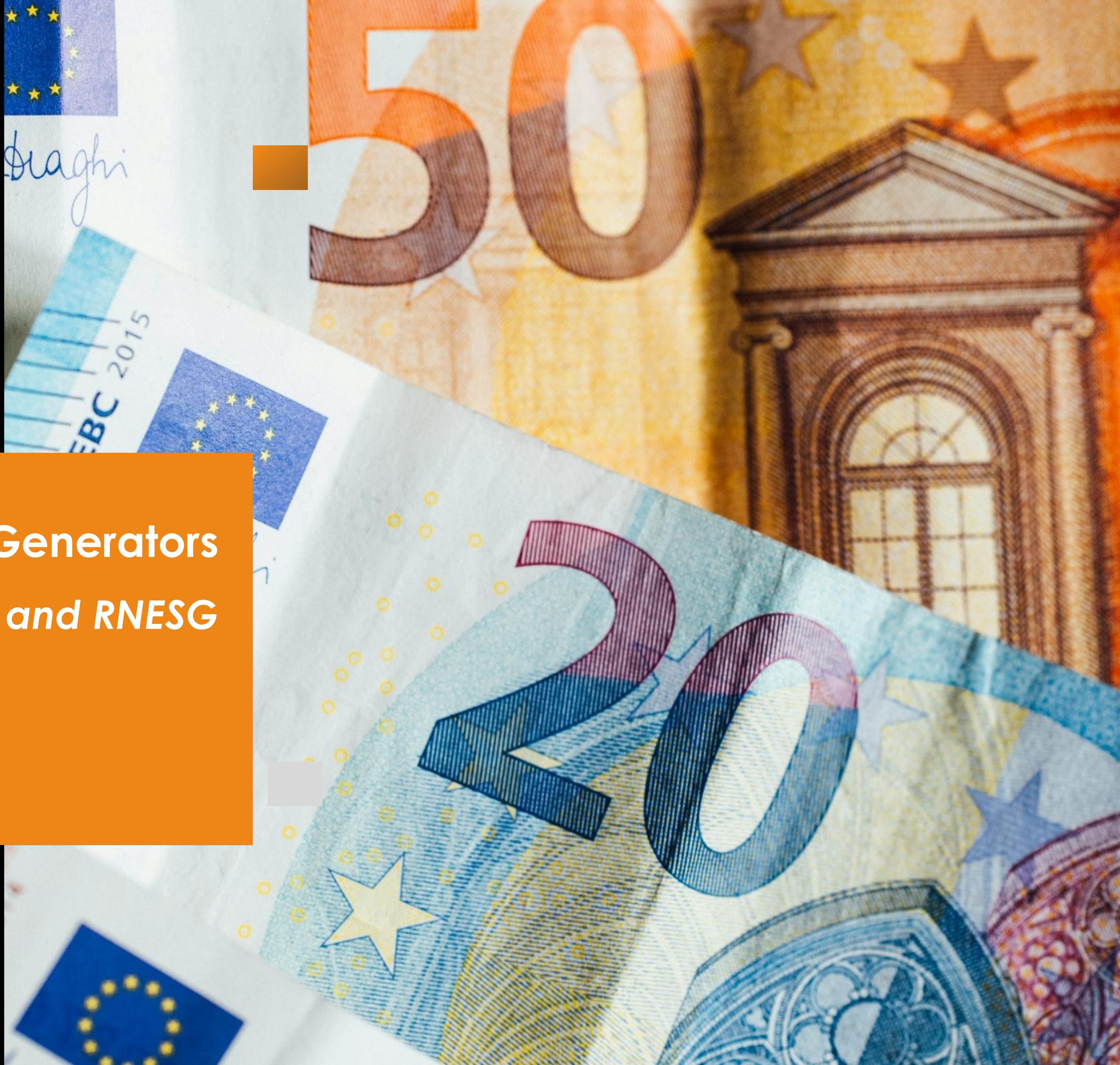
Just in Time

Economic Scenario Generators

RWESG and RNESG

February 2025



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Executive Summary

The application of Economic Scenario Generators (ESGs) in life insurance is focused primarily on understanding how interest rate fluctuations interact with policyholder behavior, particularly as these changes impact both asset performance and liability payouts. In life insurance, financial results at both the product and enterprise levels are influenced by the returns on invested premiums and the timing and magnitude of liabilities, such as mortality, morbidity, policy surrenders (which are often tied to crediting strategies), and annuity payouts.

Due to the intricate interplay of these factors over long time periods, an ESG is essential for gaining insights into a wide range of possible outcomes. By generating numerous scenarios, ESGs enable insurers to create a probability distribution, providing insight into the likelihood of various events. This is crucial for informed decision-making regarding the costs and benefits of different risks, helping insurers move beyond merely eliminating risks to mitigating them in a cost-effective manner.

The effectiveness of an ESG depends on several factors, including the use of market-consistent versus real-world scenarios, the number of scenarios considered, the forecast horizon, the economic factors being modeled, and the calibration approaches applied. These considerations are tailored to the specific application within life insurance, helping insurers better manage risk.

At a Glance

Keywords: Stochastic Simulation, Economic Scenario Generators, Real-world, EIOPA, Solvency II

01

Background

Timeline: Economic Scenario Generators in Risk management

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1

2000 – Genesis
Introduction of scenarios in risk management

2

2000-2009 – Introduction of Stochastic Models (ESG)
Adoption of more advanced stochastic models to model risk

3

2009-2016 - Solvency II
Formal integration of Economic Scenario Generators (ESGs) into the prudential supervision of the European insurance sector

4

2016-2020 - Developments and Solvency II (Review)
More sophisticated ESGs to generate not only baseline scenarios but also extreme stress scenarios and combine multiple shocks

5

2020-present - New Risks and Advanced Technologies
Inclusion of new trend topic in risk management (Climate change, AI, Big Data, Energy transition, Extreme weather events)

Timeline: Economic Scenario Generators in Risk management

Just in Time

1

2000 → Genesis of risk management with scenarios

The concept of **integrated market and insurance risk management** started to be developed. Insurance companies relied on deterministic methods and single-point scenarios to simulate future economic and financial developments. **Only a few scenarios were used**, with limited risk analysis.

Insurance regulation, including in Europe, was **less sophisticated** and did not formally require the use of stochastic models to simulate complex economic scenarios.

2

Up to 2009 → Introduction of Stochastic Models (ESG)

As **financial market volatility increased**, insurance companies adopted **more advanced stochastic models**, create by the so-called Economic Scenario Generators (**ESG**), to model risk factors such as interest rates, equity markets, credit spreads and exchange rates. ESGs were used for market risk management and long-term liabilities, although there was **no formal regulatory requirement**.

3

From 2009 to 2016 → Integration into Solvency II

The introduction of the **Solvency II Directive** (2009/138/EC) marked the **formal integration of Economic Scenario Generators** into the prudential supervision of the European insurance sector. Solvency II, fully enforced from 1st January 2016, represented a turning point in regulatory requirements, establishing a **risk-based approach** for assessing regulatory capital. Insurance companies were required to evaluate their Solvency Capital Requirement (**SCR**) using either the **standard formula** or **internal models**. The use of ESGs became particularly important in internal models, where companies were required to employ **stochastic simulations to model market risks** and assess Best Estimate Liabilities (BEL) and the Risk Margin. ESGs thus became a critical tool for forecasting economic scenarios, including future interest rates, equity market movements, market volatility, exchange rate fluctuations, default scenarios and credit spreads.

Timeline: Economic Scenario Generators in Risk management

Just in Time

4

2016–2020 → Solvency II review and subsequent developments

Insurance companies began using **more sophisticated ESGs** to generate not only **baseline scenarios** but also **extreme stress scenarios** and combined multiple shocks. The use of ESGs became crucial in integrated enterprise risk management (**ERM**) and for conducting the Own Risk and Solvency Assessment (**ORSA**). In this context, ESGs are used to generate scenarios that help companies assess future solvency, manage market risks, and align investment strategies with the company's risk profile. Increased emphasis was placed on continuous **validation and calibration of ESGs**, with companies required to demonstrate the robustness and consistency of the scenarios generated.

5

2020 to present – Advanced scenarios for new risks

With increasing complexity and interconnection of global markets, ESGs have continued to evolve in different directions:

- With growing attention to climate change and sustainability risks, ESG models (**Environmental, Social, Governance**) have been extended to include economic scenarios that reflect the **impact of climate and environmental risks on insurance portfolios** and financial assets;
- Insurance companies are increasingly using **multi-factor ESGs** that combine **financial**, **economic** and **climate variables**. This allows for more comprehensive modeling that accounts for long-term risks, such as those related to energy transition or extreme weather events;
- The use of **advanced technological tools**, such as **big data**, **artificial intelligence** and **machine learning**, has enabled the development of more advanced and flexible ESGs, capable of generating real-time scenarios and responding quickly to market changes.

02

Regulatory Framework

Regulatory Framework

The list of **regulations** that address the **topic of ESG scenarios** is here provided; their respective impacts on Reporting and Internal Models is provided in the following sections.

- Solvency II Directive (Directive 2009/138/EC) and 2020 review
- EIOPA Guidelines for ORSA (EIOPA-BoS-14/259 ITA)
- EU Delegated Regulation 2015/35
- IVASS Regulation n. 38/2018 and Circulars no. 30/2016 (Governance) and no. 14/2019 (ORSA)

Solvency II Directive

Directive 2009/138/EC	
Article 101: **Solvency Capital Requirement (SCR)**	It requires that the SCR cover all risks to which the undertaking is exposed, including market risk (interest rates, equity, currency, credit spread, etc.), which can be modeled using ESG. The calculation of the SCR, through the standard formula or internal model, must take into account future economic scenarios.
Article 112: **Internal models**	Companies using internal models to calculate the SCR must demonstrate that these models are appropriate to represent actual risks, including market risk. ESGs are fundamental to the modeling of financial risks in internal models.
Article 120: **Validation of the internal model**	Describes the internal model validation process, requiring that they be tested using market scenarios. ESGs are used to generate these scenarios.
Article 121: **Documentation of the internal model**	Requires that companies adequately document their internal models, including calibration methods, which may include ESG for the modeling of financial risks.
Article 122: **Statistics and model quality**	Requires companies to ensure that internal models, including economic and financial scenarios, adequately reflect expected economic reality and stress scenarios.
Article 134: **Risk management**	Companies must put in place risk management systems that include an assessment of future risks. ESGs are used to generate economic scenarios useful for this assessment.

EIOPA Guidelines and EU delegated regulations

EIOPA-BoS-14/259 ITA	
Guidelines 5-9: Forward-looking scenarios and stress tests	These guidelines specify that the ORSA must include forward-looking risk analyses, through future economic and financial scenarios, as well as stress tests. ESGs are essential for generating baseline and adverse scenarios.
Guideline 11: Forward-looking approach	Companies must use forward-looking scenarios, calculated through forward-looking models, such as ESGs, to assess the evolution of regulatory capital (SCR) over time.

Commission Delegated Regulation (EU) 2015/35	
Article 169: Risk management requirements	This article requires companies to continuously monitor and assess all risks, including market risks, which can be managed with the help of ESG to model future scenarios.
Article 171: ORSA (Own Risk and Solvency Assessment)	Specifies that companies must regularly perform ORSA and assess their exposure to future risks. ESGs are used to model future market scenarios required for these assessments.
Article 174: Market risk models in internal models	Companies must demonstrate that their internal models adequately represent market risk, including future economic scenarios generated through ESGs.

IVASS Regulation

IVASS Regulations and Circulars		
Regulation no. 38/2018 – Internal Models	**Calibration of internal models**	Requires that internal models use appropriate economic scenarios for the calibration of market risk, including interest rates, equities, and other risks that can be modeled through ESGs.
	Validation of internal models	Companies must provide evidence of the validity of internal models, including the simulation of economic scenarios generated by ESGs.
Prot. 0008712/18 of 12/01/2018	**Supervisory Regulations and Policies Department**	Describes how companies must integrate economic scenarios (both forward-looking and adverse) into their risk management processes. ESGs can be used to model such scenarios.

03

(Life) Insurance Application

Business Applications in Insurance and Pensions Industries

Life Insurance Application

Business Applications in Insurance and Pensions Industries

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Applications in life insurance

ESGs are used to **evaluate** the **effects of interest rate** fluctuations on policyholder behaviors and options, such as lapses and surrenders. These models are essential for **life liability valuation**, **stress testing**, economic capital assessment, strategic asset allocation, and duration analysis. ESGs also aid in **modeling investment returns** and policy payouts tied to mortality, morbidity, or annuity benefits, offering valuable insights into potential outcomes and scenario probabilities.

Applications in the pension industry

ESGs **support liability-driven investment** (LDI) **strategies**, analyzing sensitivities in pension funding, and guiding pension risk transfer decisions. ESGs are used to evaluate investment strategies, forecast funding needs, and assess various funding approaches, such as large initial contributions versus steady contributions over time. Additionally, ESGs enable plan sponsors to **compare risk transfer options**, such as freezing plans or transferring them to external entities.

Applications in property and casualty (P&C) insurance

ESGs are used to **assess the impact** of **inflation** on **liabilities**, assets, and **economic cycles** influencing exposures and pricing. They play a crucial role in **modeling complex liability development**, particularly for **casualty products** with extended settlement periods, and for property products that are sensitive to volatile factors like weather patterns and economic shifts. ESGs are viewed as essential tools for enterprise risk modeling within the P&C insurance sector.

Comparison of the main areas of use in the insurance field

Just in Time

Life Liability Valuation	**Life insurance liability valuation** requires modeling **interest-sensitive cash flows** and **policyholder behavior** under various economic conditions. ESGs generate a range of market-consistent scenarios, accounting for **extreme events** and **option-like features** in insurance contracts. Many scenarios may be needed to ensure accuracy in valuation, particularly in extreme situations.
Effective Duration Analysis	ESGs help calculate the **effective duration of interest-sensitive liabilities** by generating a set of market-consistent scenarios and shocking them to **reflect interest rate changes**. This allows for better measurement of price sensitivity to interest rates.
Stress and Cash Flow Testing	ESGs support **deterministic** and **probabilistic stress testing**. By using stochastic simulations, companies can evaluate the **likelihood of extreme events** and better assess the adequacy of their reserves. Reverse stress testing identifies the most damaging scenarios for the insurer.
Economic Capital	ESGs are crucial for **economic capital calculations**, which focus on tail events that could threaten a company's **solvency**. A large number of scenarios is needed to accurately represent extreme risks.
Strategic Asset Allocation (SAA)	ESGs help **optimize asset allocations** by evaluating how assets and liabilities perform across a range of economic scenarios. This process helps insurers find **efficient**, **risk-adjusted investment strategies** aligned with liability behavior.

04

Real-world, Risk-neutral and Market Consistent

Real-world, Risk-neutral and Market Consistent Definition

Real-world, Risk-neutral and Combined Calibration

Risk-neutral and Real-world

Just in Time

The relationship between the concepts of **Real-world** and **Risk-neutral scenarios** is determined by the implications introduced by the **economy** or the **market**. The use of different types of scenarios is dictated by **Regulators**.

Real-world ESG

Real-world scenario generators are designed to realistically simulate future economic conditions over time, using the **P-measure** (real-world probabilities).

Purpose
These scenarios are ideal for risk management, answering questions like "How bad could things get?" and "How likely is that?".

Features
- Centered on realistic expectations and include risk premiums.
- Used primarily for market risk assessment and stress testing.

Usage
Suitable for simulations evaluating risk based on real and plausible market events.

Risk-neutral ESG

Risk-neutral scenario generators use the **Q-measure** (risk-neutral probabilities), giving more weight to adverse scenarios. These scenarios ignore risk premiums and focus on risk-free rates.

Purpose
Used for market-consistent valuation, such as for options and derivatives, reproducing current market prices.

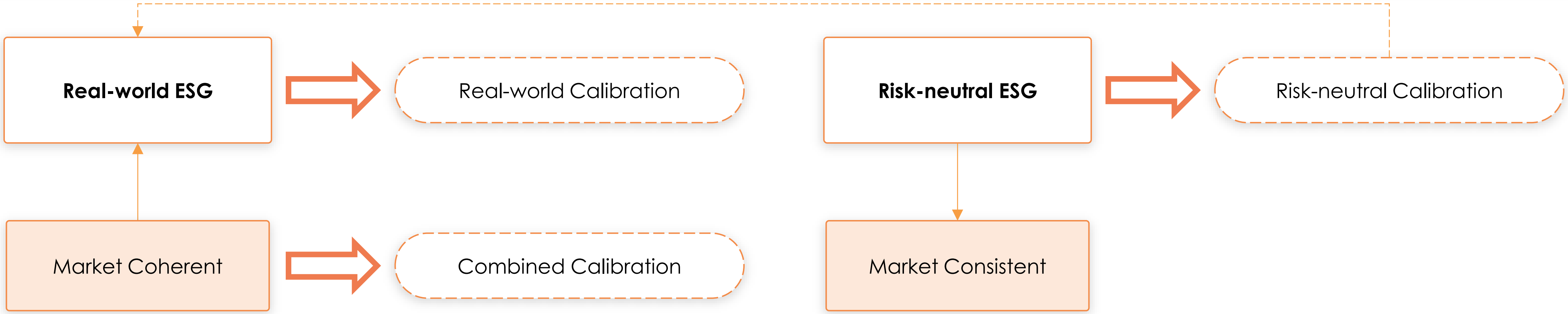
Features
- Greater probability of adverse events compared to real-world scenarios.
- Use risk-free discount rates and simulate outcomes that reflect the current market price structure.

Usage
Optimal for calculating the market value of financial instruments with uncertain payoffs.

Risk-neutral, Real-world, Market Consistent and Coherent

Just in Time

The relationship between the concepts of **real World** and **risk-neutral scenarios** is determined by the implications introduced by the **economy** or the **market**. The use of different types of scenarios is dictated by **regulators**.



Market-Consistent → Market-Coherent

The term "**market-consistent**" is commonly associated with the **risk-neutral approach**. To prevent misunderstanding, the term "**market-coherent**" may instead be used to describe a **real-world model** calibrated to **align with market prices**.
A **market-consistent** scenario is calibrated to be **consistent** with current market prices, often associated with the **Q-measure** of risk-neutral generators.

Purpose
Ensures that the valuation of financial instruments, especially derivatives, aligns with observable market prices.

Features
- Accurate reproduction of market prices based on volatility and expected returns.
- Used in regulatory and financial reporting contexts

Usage
Necessary when ensuring values are aligned with observable market prices

Risk-neutral Calibration

Just in Time

Risk-neutral Calibration

Risk-neutral calibration is a method in financial modeling that adjusts model parameters to match current market prices, ensuring **market-consistent valuations** by using the **Q-measure**, a probability measure that **disregards real-world risk premiums**. This approach is crucial for valuing **derivatives** and less frequently traded instruments, as it aligns valuations with **immediate market prices** rather than projecting realistic long-term scenarios.

Calibration Process

- Uses closed-form mathematical expressions that describe the **prices** of various assets, including derivatives, and enables **iterative adjustment** of parameters to replicate observed market prices.
- Since market prices fluctuate, risk-neutral calibration may be **frequently updated** to stay aligned with current market conditions.
- In some cases, a risk-neutral model requires a "volatility surface," an array of **volatilities for specific options** to improve accuracy in replicating market prices.

Key Features

- **Non-realistic parameters**: Risk-neutral parameters lack concrete real-world meaning; they are used solely to enhance alignment with market prices.
- **Volatility Surface**: In models like Black-Scholes, using different volatility levels for options with varying strike prices and expirations allows a better fit with observed market prices, although this approach limits coherence for long-term simulations.

Real-world Calibration

Real-world Calibration

Real-world calibration is a method used in financial modeling to generate **realistic long-term scenarios** by **reflecting** the **expected evolution** of **economic variables** under the real-world probability measure (**P-measure**), which includes risk premiums and may diverge from current market values. This approach is ideal for **long-term simulations** and risk analysis applications, such as **financial risk management** and **actuarial reserve** calculations, as it accurately represents the future behavior of variables like interest rates and equity returns.

Calibration Process

- Real-world calibration focuses on how state variables move over time, analyzing both **historical consistency** and future expectations.
- Parameters like **volatility** and **reversion point** hold a real meaning: they are **based on historical dynamics** and economic expectations, making this calibration far more tangible than risk-neutral calibration.

Key Features

- **Real risk premium**: Unlike risk-neutral calibration, real-world calibration includes a positive risk premium, reflecting the market risk associated with uncertain investments.
- **Concrete parameter significance**: Parameters like the reversion point and volatility hold real-world meaning and imply economic expectations consistent with long-term observations. For example, a short-term interest rate might be calibrated to reflect its likely future trend, not just the current value.

Market Coherent - Combined Calibration

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Market Coherent – Combined Calibration

Combined calibration seeks to **integrate the strengths** of r**isk-neutral** and **real-world** calibration, creating a **"market-coherent"** model that **aligns with current market prices** while realistically reflecting price evolution over time using real-world probabilities (**P-measure**). This approach supports accurate **long-term simulations** and **risk analysis applications**, making it suitable for financial risk management and actuarial reserve calculations by capturing both **immediate market valuations** and **realistic future scenarios**.

Calibration Process

- Distinguishes **real probabilities** (P-measure) from **risk-neutral probabilities** (Q-measure), keeping **both parameter sets** within an arbitrage-free model.
- The real-world path of the short-term rate is adjusted to remove **long-term risk premiums**, while risk-neutral parameters are used to calculate **prices consistent** with the **current market**.

Key Features

- **Combined use** of **real-world** and **risk-neutral** parameters: it is crucial that the risk premium, reflected in the difference between risk-neutral and real-world parameters, remains positive to simulate realistic scenarios with expected higher returns for riskier investments.
- **Consistency Constraints**: risk-neutral calibration must be constrained by real-world calibration to avoid unrealistic parameters. For instance, term premiums can be verified by comparing interest rates generated by both parameter sets.

From RW to RN probabilities: Vasicek model for Interest Rates

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Vasicek model

$$(next\ period\ value) = (current\ value) + (expected\ drift) + (random\ shock)$$

$$r_{t+1} = r_t + \kappa(\theta - r_t) + \sigma W_t$$

κ = mean reversion strength or speed
θ = mean reversion point
σ = volatility
Wt = a random number from a Gaussian distribution with mean zero and variance one

Probably the best-known and simplest interest rate model, the Vasicek model treats the short-term risk-free interest rate as a **mean-reverting** random walk.

The Vasicek model assumes a certain kind of market behavior. Aspects of that behavior are that the **volatility** is **constant** and that **interest rates** can become **negative** if enough negative random shocks accumulate.

The discrete model above is expressed as a stochastic differential equation in continuous time: $dr = \kappa(\theta - r)dt + \sigma dW$

Market Price of Risk

The change in measure from real-world (the **P-measure**) to risk-neutral (the **Q-measure**) in the Vasicek model is accomplished by modifying the random shock term, replacing dW with $d\hat{W} = dW + \lambda$.

λ represents the so-called **Market Price of Risk**: to define it, we start with the idea that risk-averse investors require a **higher expected** or **average return** on **riskier investments**. We measure risk by the volatility of the market price.

$$\text{Market price of risk} = \lambda = \frac{(Expected\ average\ return) - r}{standard\ deviation\ of\ price}$$

Vasicek formula including λ

$$dr = \kappa(\theta - r)dt + \sigma(dW + \lambda) = \kappa\left(\left(\theta + \frac{\sigma\lambda}{\kappa}\right) - r\right)dt + \sigma dW$$

This equivalence between changing the random term and the drift term is what makes this and many similar models mathematically tractable so that a fixed-form equation for the spot price at any maturity can be derived. This equivalence is also what makes the P-measure and the Q-measure "**equivalent Martingale measures**".

05

Scenario Simulation

Stochastic Scenario Simulation

Copula Scenario Simulation

Introduction

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An ESG is used to generate a **distribution of simulated paths** for one or more financially relevant variables, while reflecting both **suitable marginal distributions** for each variable and **coherent variables interdependencies**.

To create an Economic Scenario Generator, essentially one of the following **two approaches** can be chosen:

Stochastic scenario simulation

Based on parameters rooted in **historical data** (for the marginal distributions) and on **correlation matrices** (for the infra-variable dependencies), this method leverages **mathematical models** to generate a range of possible future outcomes, reflecting the uncertainty inherent in economic markets.

Copulas scenario simulation

Copulas are statistical tools used to **model the dependence** between multiple economic variables, especially when the relationships are **non-linear** or **non-normally distributed**. They allow the institution to **separate marginal distributions** from the **dependency structure**, at the same time offering more flexibility in the modeling of joint distributions (e.g.: accurate tail dependencies).

While the **first approach** is **simpler to implement** and interpret, it may oversimplify some aspects of the financial modeling, such as how different risks relate to each other. The copula-based approach on the other side, while **more complex to work with**, can successfully model **more complex interdependencies** and guarantees a **better control over the evaluation of extreme events**.

Summary of ESG approaches

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The following table provides an **overview** on the **main characteristics**, **advantages**, **limitations** and typical **applications** of the two approaches to **Economic Scenario Generator tools**. Details on each of the two approaches can be found in the next pages.

	Stochastic scenario simulation	Copulas scenario simulation
Theoretical foundation	Based on stochastic differential equations and probability distributions	Sklar's theorem for joint distribution decomposition
Core components	• Risk factor models (e.g., Black, CIR, GBM) • Correlation matrices for dependencies	• Marginal distributions for individual risk factors • Copula functions to model complex dependencies
Implementation steps	1. Model calibration to historical data 2. Generating correlated random scenarios 3. Ensuring cross-asset consistency	1. Fitting marginal distributions 2. Estimating copula parameters 3. Sampling from copulas and marginals
Advantages	• Straightforward implementation • Well-understood mathematical foundation	• Flexible modeling of non-linear dependencies • Accurate representation of tail risks and extreme events
Limitations	• May oversimplify complex relationships • Potential to underestimate tail risks	• Higher complexity in calibration and implementation • Requires deeper statistical expertise
Typical Applications	• Basic portfolio simulations • Option pricing • Risk-neutral scenarios	• Advanced enterprise-wide risk management • Complex structured products • Stress testing and tail risk assessment

Stochastic scenario simulation – technical point of view

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Regarding the **stochastic approach** to Economic Scenario Generating, different **mathematical choices** can be made depending on the specific risk category to be modeled. Here we present some **common models** and their main **characteristics**, the list is clearly not exhaustive.

Risk component	Viable modeling approach	Core concept	Advantage	Limitations
Interest rate	**CIR model**	Square-root **diffusion process** ensuring non-negative rates	Interest rates remain strictly positive	Less flexible in fitting observed term structures
Equity	**Black-Scholes model**	**Geometric Brownian motion** with constant volatility	Closed-form solutions for option pricing	Assumes constant volatility across strikes and maturities
Interest rate volatility	**Local volatility model**	**Volatility** as deterministic function of time and rate level	Perfect fit to market option prices	Poor prediction of future volatility surfaces
Equity Volatility	**Local volatility model**	**Volatility** as function of asset price and time	Consistent with observed option prices	Unrealistic dynamics under large market moves
Spread	**Shifted Black-Karasinski model**	**Log-normal process** with shift parameter for spreads	Can handle negative spreads	Mean reversion can be too strong
Inflation	**Jarrow-Yildirim model**	**Three-factor model** linking nominal rates, real rates, and inflation	Consistent pricing of inflation-linked products	High number of parameters to calibrate
Foreign Exchange	**Dupire model**	**Local volatility approach** applied to FX rates	Matches market smile exactly	Requires complete option surface for calibration, cannot preserve the smile for forward-starting trades

Stochastic scenario simulation – process flow

The single approaches to risk factor scenario generating are one of the building blocks of the general ESG process. The entirety of the ESG process in case of a stochastic approach is here summarized.

Scenario Generation

BUILDING BLOCKS

Risk factor models

Dependency structure

- Identifying a **suitable model**
- **Calibrating** the model **parameters** to fit market data
- Determining and adjusting **between** and **within-asset relationships**

SIMULATION PROCESS

Initialization

Path Generation

Risk Factor evolution

- Defining **horizons** and **time steps**
- Generating correlated and consistent **random evolution paths**

INTEGRATION FRAMEWORK

Consistency checks

Calibration hierarchy

Scenario output

- Verifying **conditions** such as market price alignment
- Checking **calibration hierarchies** and evolution **coherence**

Copula scenario simulation – technical point of view

Just in Time

Regarding the **copulas approach** to Economic Scenario Generating, the choice of the right pair of copula and marginal distributions is key to modeling scenarios which at the same time reflect the original data and respect essential characteristics.

The cornerstone of the **copula-based approach** is **Sklar's theorem**, which states that any multivariate distribution function can be **decomposed** into its **marginal distribution functions** and a **unique copula function** that describes the **dependence structure** between the variables.

Mathematically, Sklar's theorem can be expressed as:

$$H(x_1, x_2, \dots, x_n) = C(F_1(x_1), F_2(x_2), \dots, F_n(x_n))$$

Where:

- H is the joint distribution function
- F_i are the marginal distribution functions
- C is the copula function that links the marginals

This **separation** of the marginals and the dependence structure is the key advantage of the copula approach, as it allows for **flexible and robust modeling** of complex relationships between risk factors.

Various **families of copula functions** can model different types of dependencies:

1. **Elliptical Copulas**, such as **Gaussian copula** and **Student-t copula**, which can capture symmetric and linear dependencies
2. **Archimedean Copulas**, such as Clayton, Gumbel and Frank copulas, which allow for asymmetric and tail dependencies
3. **Vine Copulas**, which are based on a hierarchical structure and allow to decompose the joint distribution into a nested set of bivariate copulas

The copula approach allows for the use of **various parametric and non-parametric distributions as the marginals**, including:

- **Normal**/Lognormal
- Generalized **Pareto**
- **Extreme Value**
- **Empirical distributions**
- others, depending on the characteristics of the risk factors.

The flexibility in choosing the appropriate marginal distributions is crucial for **accurately capturing the statistical properties of individual risk factors**.

Copula scenario simulation – process flow

Just in Time

This flow diagram summarizes the ESG process in the case of a copula approach.

Scenario Generation

BUILDING BLOCKS

- Marginal distributions
- Copula function choice

- Fitting **marginal distributions** to historical data
- Choosing the **dependence structure** between risk factors

SIMULATION PROCESS

- Initialization
- Scenario Generation
- Refinement

- Estimating **copula parameters** from market information
- Applying **inverse probability transformation** to get correlated values
- Refine **marginal distributions** and copula specifications

INTEGRATION FRAMEWORK

- Consistency checks
- Backtesting and validation
- Risk aggregation

- **Statistical testing** for goodness-of-fit
- **Backtesting** on historical data
- Checking **proper modeling** of **extreme events** and other properties

06

Risk Management and Actuarial Function

Actuarial Function

The **Actuarial function** contributes to the company's financial stability, ensuring that *ESGs* are effectively implemented and used for risk management and regulatory compliance. In the generation of economic scenario generators (ESGs) and the assessment of technical provisions and capital requirements. Key responsibilities include:

01 **Coordinating the Calculation of Technical Provisions**:
This includes ensuring that the methodologies and models for generating economic scenarios and the assumptions underpinning them are appropriate, as specified in Article 48 of the Solvency II Directive;

02 **Ensuring Data Quality**:
The actuarial function evaluates the sufficiency and quality of data used in projections, aiming for completeness and accuracy to support reliable actuarial estimates and technical provisions. Consistent data quality is essential for maintaining robust results over time;

03 **Evaluation of Assumptions and Scenario Review**:
Actuaries perform "actual versus expected" analyses, comparing projections with actual outcomes. This process ensures that assumptions and models remain aligned with historical experience and economic conditions, improving the accuracy of forecasts and risk models;

04 **Opinion on Underwriting and Reinsurance Policy**:
The actuarial function offers insights into the adequacy of underwriting policies and reinsurance strategies, helping to manage economic risks and optimize reserve structures across various risk scenarios;

05 **Contribution to Risk Management**:
The actuarial function plays a central role in risk management, particularly in modeling the risks involved in calculating capital requirements. ESGs are key tools here, providing long-term risk scenario analysis that supports strategic planning and effective capital allocation.

Risk Management

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In the context of Economic Scenario Generators (ESGs), risk management plays a crucial role in identifying, measuring, and mitigating long-term financial and insurance risks. ESGs generate simulated scenarios for key economic variables allowing insurance companies to assess the impact of a wide range of economic situations. Here's how risk management applies to ESGs.

01 Risk Identification

- ESGs help identify **major economic** and **financial risks** the company is exposed to, including market risks (such as interest rate, and currency risks) and policyholder behavior risks.
- The risk management function uses **ESGs to pinpoint potential adverse scenarios**, like significant interest rate hikes or a sudden stock market decline, which could affect both the assets and liabilities of the firm.

02 Risk Measurement and Quantification

- ESGs produce a wide **range of economic scenarios** that enable the calculation of risk metrics, such as **Value at Risk** and Tail Value at Risk, at different confidence levels. These metrics help quantify **extreme event risk** and assess the company's resilience under adverse economic conditions.
- The output of ESG models is often used within the **Solvency II framework** to calculate economic capital requirements, particularly through internal models that must be regulator-approved.

03 Stress Testing and Scenario Analysis

- ESGs provide simulated economic scenarios to **support stress tests** and **scenario analysis**, helping understand how extreme events would impact the firm's balance sheet.
- These stress scenarios are essential for the **Own Risk and Solvency Assessment**, a key component of Solvency II, which requires companies to continually assess their solvency under various scenarios.

Strategic Planning and Capital Allocation 04

- ESG outputs are also used to **support long-term strategic planning** and optimal capital allocation. By analyzing various economic scenarios, insurers can design portfolios that **balance risk** and **return effectively**.
- Companies can evaluate how changes in interest rates or equity returns might impact liquidity and available capital, enabling them to make informed decisions on **hedging**, **reinsurance**, managing **interest rate risk**.

Model Validation and Verification 05

- RM is responsible for the **validation of ESGs** to ensure that models represent economic realities. This includes verifying assumptions and calibrating the model based on market data and historical experiences.
- The RM function collaborates with the actuarial function to ensure ESGs remain **relevant to market changes** and comply with regulatory requirements, such as market consistency and calibration for "real-world" and "risk-neutral" scenarios.

Communication and Reporting 06

- The results from ESGs are used by the risk management function to inform the **board of directors** and other **business functions** about **potential financial risks** and their impact on the company's capital and solvency.
- Reporting on the results of stress tests and scenario analyses helps management **understand emerging risks** and **develop proactive response strategies**.

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Implementation of the designed **solutions** in bank departments **Methodological support** to both **systemically important financial institutions** and **supervisory entities**

Solution

Advanced **software solutions** for **modeling, forecasting, calculating** metrics and **integrating** risks, all on cloud and distributed in Software-as-a-Service (**SaaS**)

Company Profile

iason is an international firm that consults Financial Institutions on Risk Management. Iason integrates deep industry knowledge with specialised expertise in Market, Liquidity, Funding, Credit and Counterparty Risk, in Organisational Set-Up and in Strategic Planning.

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This document was prepared in collaboration with Leonardo Bandini who at the time was working for Iason Consulting.

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