# An Integrated Approach to Cost-Risk Analysis in Public Debt Management


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# Forecasts *vs.* Simulations

*"Nothing is more difficult, and therefore more precious, than to be able to decide"* (Napoleon)

*"The only function of economic forecasting is to make astrology look respectable"* (Ezra Solomon)

Simulation may support *What-if* analysis in the evaluation of the risk factors impact and/or of a given policy in many fields, including public debt management.

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# Composition of Italian Public Debt Management portfolio

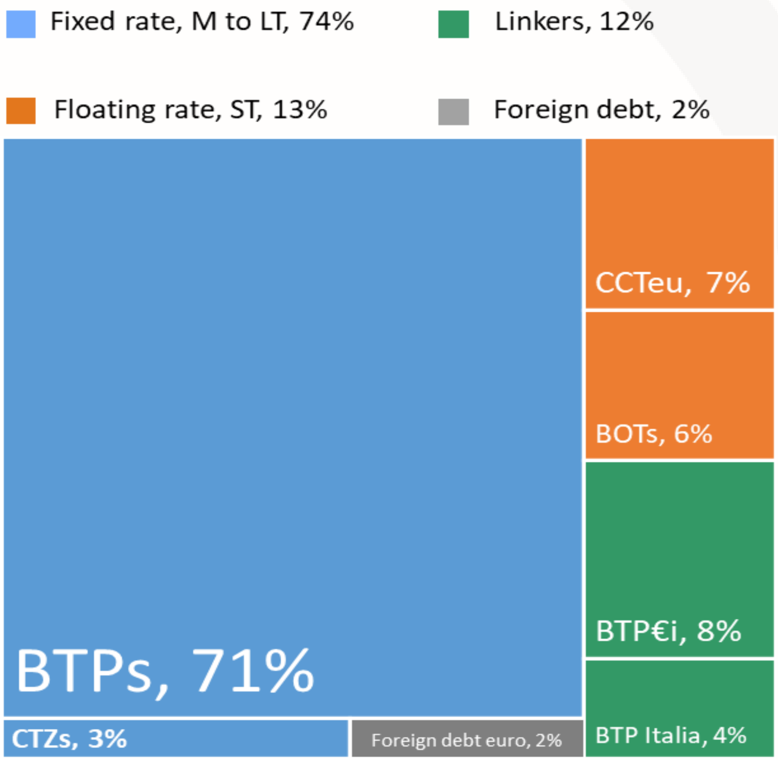
## Securities

2,025  Bln € as for June 30, 2019

~ 190 outstanding securities (ISIN codes, T-Bills not included)

~ 100 auctions p/year

Fixed or floating rates, Euro inflation, Italian inflation




## Derivatives

106 Bln € notional as for June 30, 2019
- CSA / CVA

## Liquidity buffer

48 Bln € monthly average in 2018

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# Managing the portfolio…

Choices to be made include:

- Short term *vs.* medium-long term securities
- Fixed rate *vs.* Inflation (which one?) based
- Euro *vs.* foreign currency securities…
- Derivatives transactions

Taking into account that

$$CD(t) = CD(t-1) + FLOW(t) + S(t) > X \text{ €}$$

*where*

*X set by Debt manager*

$CD(t)$ is the balance of the Treasury cash account at time $t$;

$FLOW(t)$ is the cash flow of the portfolio at time $t$;

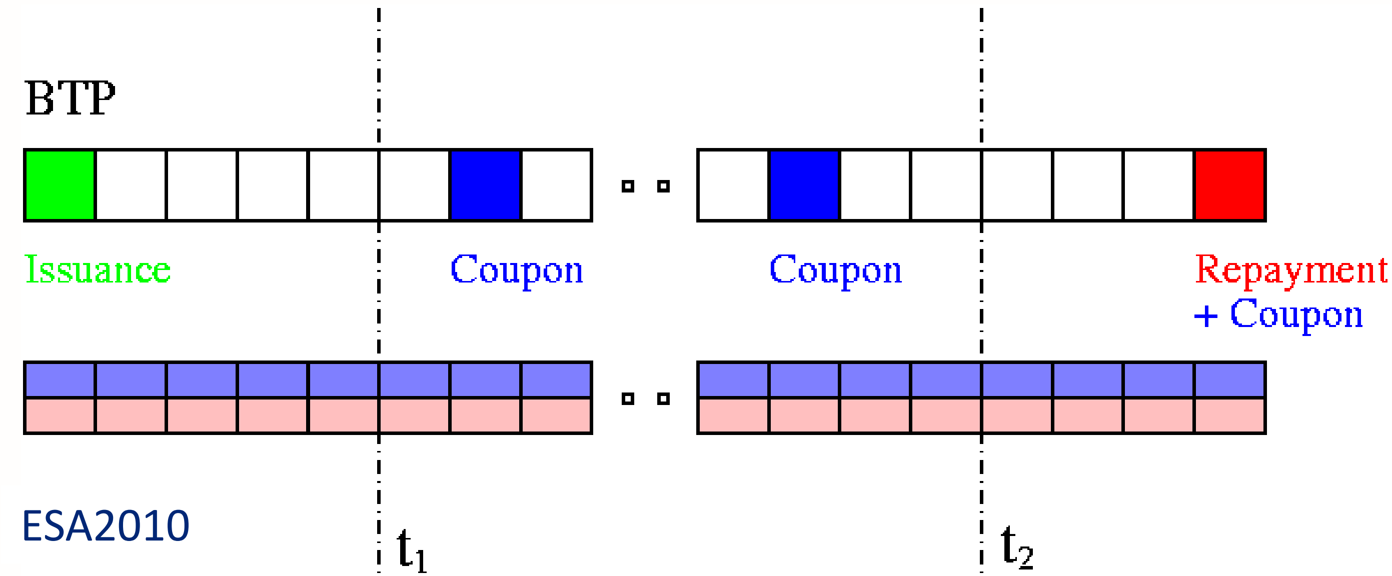
$S(t)$ is the primary budget surplus/deficit at time $t$.

The above relation must be fulfilled at **any** time $t$

# … also dealing with European Accounting rules

## Finding a trade-off between cost and risk according to the ESA2010* metrics

Given a fixed temporal horizon, the ESA2010 measures the interest costs in the accrual accounting method, *i.e.,* as if the security costs were spread over its whole lifetime:




*European System of National and Regional Accounts 2010

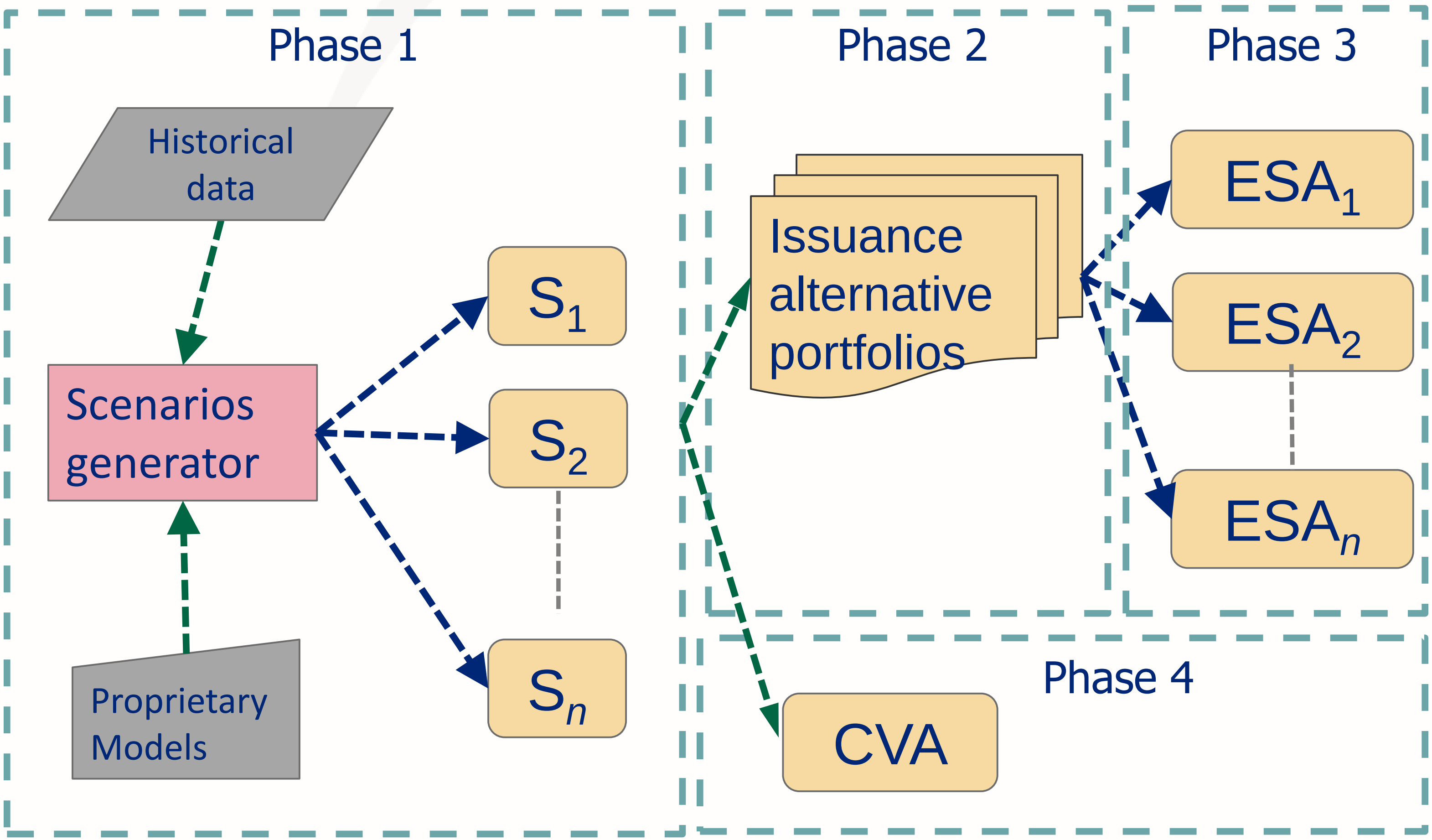
# Issuance Portfolios Analysis Software (SAPE) Timeline

**2003**
Starting as a research project funded by the Italian Research and Education Ministry

**2009**
Insourcing at the Italian Treasury supported by the in-house IT Company Sogei

**Today**
A proprietary Treasury tool, involving Research Institutions, State-owned IT Company and Treasury Department (Public debt Directorate)

# Numerical Simulations and Cost-Risk Analysis



# SAPE – Main features

- SAPE analyzes cost and risk of government securities issuances
  - SAPE defines the efficient frontier that supports the portfolio-selection process
- SAPE calculates with the highest accuracy the financial quantities relevant for the management of public debt, *e.g.*, the cash flow, time to maturity metrics, *etc.*
- A key component of the SAPE software is the module generating out-of-sample scenarios for the term structures of the interest rates
  - It makes possible a quantitative measurement of expected exposure vis-à-vis volatility of the yield curve
- Starting from 2014, additional analyses are possible like the estimation of counterparty risk related to derivatives instruments, *e.g.* the calculation of the Credit Value Adjustment (CVA).

# Phase 1 - Interest rates scenarios generation (1)

- Adopt Nelson-Siegel-Svensson (NSS*) specification:

$$y(\tau) = \beta_1 + \beta_2 \left[\frac{1-\exp(-\tau/\lambda_1)}{\tau/\lambda_1}\right] +$$
$$\beta_3 \left[\frac{1-\exp(-\tau/\lambda_1)}{\tau/\lambda_1} - \exp(-\tau/\lambda_1)\right] + \beta_4 \left[\frac{1-\exp(-\tau/\lambda_2)}{\tau/\lambda_2} - \exp(-\tau/\lambda_2)\right]$$

where y(t) is the zero-coupon rate for maturity t and $\beta_1, \beta_2, \beta_3, \beta_4, \lambda_1, \lambda_2$ are estimated parameters.

- Parameters have an economic interpretation that implies the following restrictions:

$$\beta_1 > 0,\ (\beta_1+\beta_2) > 0,\ \lambda_1 > 0,\ \lambda_2 > 0$$

- Setting fixed values for $\lambda_1$ and $\lambda_2$ yields lower volatility in estimates (in general due to local minima) and better control of the evolution process of b parameters

*Charles R. Nelson and Andrew F. Siegel. Parsimonious Modeling of Yield Curves. Journal of Business, 60(4):473–489, 1987.
**Lars E.O. Svensson**. Estimating and Interpreting Forward Interest Rates: Sweden 1992–1994. IMF Working Paper 94/114, 1994.

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# Phase 1 - Interest rates scenarios generation (2)

- In the original NSS specification, the parameters $\beta_1$, $\beta_2$, $\beta_3$ can be interpreted in terms of level, slope and curvature of the yield curve
- The second medium term factor, $\beta_4$, is useful for a better fit of data including long term maturities (> 10 years): more flexibility
- After in-sample estimation, we perform a joint calibration of sovereign, BEI and euroswap curves in order to identify an evolution process for parameters $\beta_1$-$\beta_4$ and produce out-of-sample forecasts (scenarios).

# Actual (blue) vs fitted (orange) sovereign and BEI yields (10y) in sample calibration

Fitted

Actual

BTP 10y


BEI 10y

# Phase 1 - Interest rates scenarios generation (3)

Following Diebold and Li* (2006), we adopt a multivariate specification based on a vector autoregression (VAR) model:

$$\beta_t = m + A\beta_{t-1} + e_t$$

where β is a 12 elements vector for β parameters, m is a vector of intercepts, A is a 12x12 coefficient matrix describing the autoregressive scheme of parameters. The innovations $e_t$ are extracted as residuals of the historical data.

The VAR model, after estimation and general-to-specific simplification for eliminating non-significant coefficients, is simulated out-of-sample producing joint scenarios for the three sets of βs.

USD swap curve is calibrated separately and its level $\beta_1$ enters in the level equation of euroswap curve.

***Francis X. Diebold and Canlin Li**. Forecasting the Term Structure of Government Bond Yields. Journal of Econometrics, 130(2):337–364, 2006.



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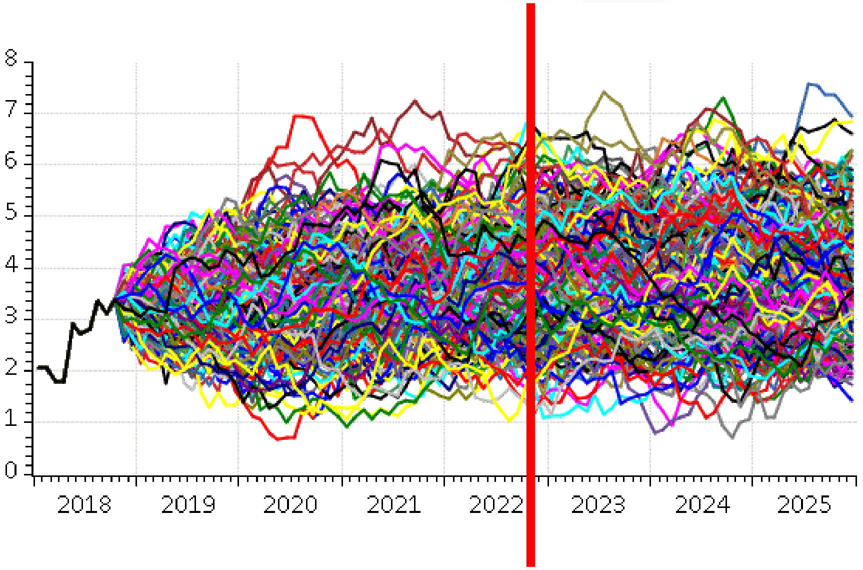
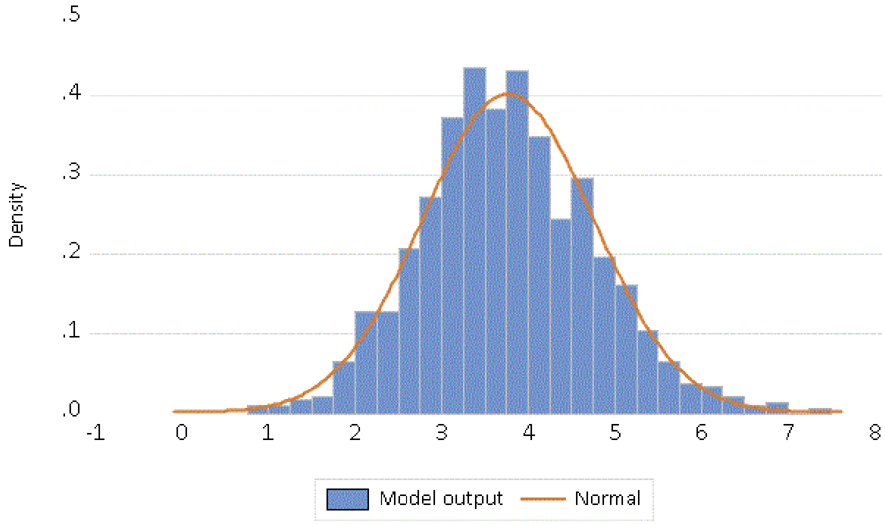
# Phase 1 – Out-of-sample BTP 10y





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# Phase 1 - Interest rates scenarios generation (4)

- Altavilla* *et al.* proposed in 2013 a methodology for anchoring (tilting) the yield curve using exogenous priors on short term rates (*e.g.,* survey data).
  - The anchoring methodology is independent from the base model
- The basic idea is to rotate (tilt) the yield curves generated by the base model, incorporating the exogenous priors on short rates, without re-estimating the parameters or changing the original specification.
- In 2014 we implemented the anchoring methodology within the VAR model and more recently we extended it to support multiple anchoring points.

***C. Altavilla, R. Giacomini and G. Ragusa,** Anchoring the Yield Curve Using Survey Expectations, *Journal of Applied Econometrics*, Vol. 32, No. 6, 2017, pp. 1055-1068

# Phase 2-3 ESA2010 Cost Function characterization

Simplifying hypotheses for an analytical treatment

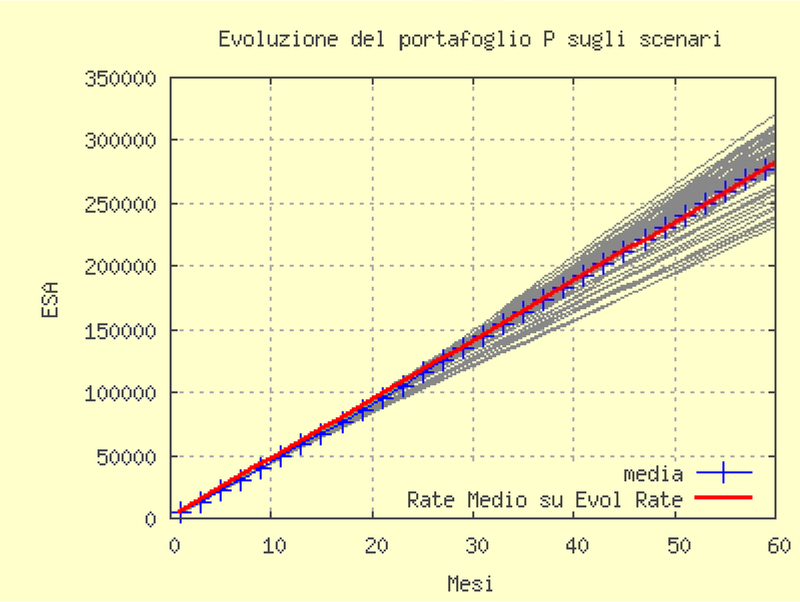
1. The price of each coupon bond is 100
2. Each bond is issued in the first day of the month and the ESA2010 is computed on a monthly base
3. The total issued quantity of each bond does not depend on time and it is proportional to the total amount of debt and uniformly spread along the bond lifetime:

$$E\left(ESA2010(T)\right) = \sum_{t=1}^{T} \frac{D}{12} \sum_{k \in K} x_k E(r_k) = \left( \frac{D}{12} \sum_{k \in K} x_k E(r_k) \right) T$$

***Linear (with respect to the time) growth of the ESA2010 with a slope depending on debt composition and interest rates***

# Phase 2-3 Choosing the cost variable…

Starting on the current debt composition and a candidate issuance policy for a period of 4-5 years, we compute the ESA2010 evolution for a number of interest rates scenarios.




Commonly used choices for the cost function are the last points of the ESA evolution.
By using the probability distribution of those points we obtain cost and risk measures.

$$R_1 = ESA(1)$$ → Initial growth-rate

$$R_m = \frac{ESA2010(T)}{T}$$ → Average (final) growth rate

$$R_e = \frac{\sum_{t=0}^{T} ESA2010(t)}{\sum_{t=0}^{T} t^2}$$ → Best fit of the growth rate

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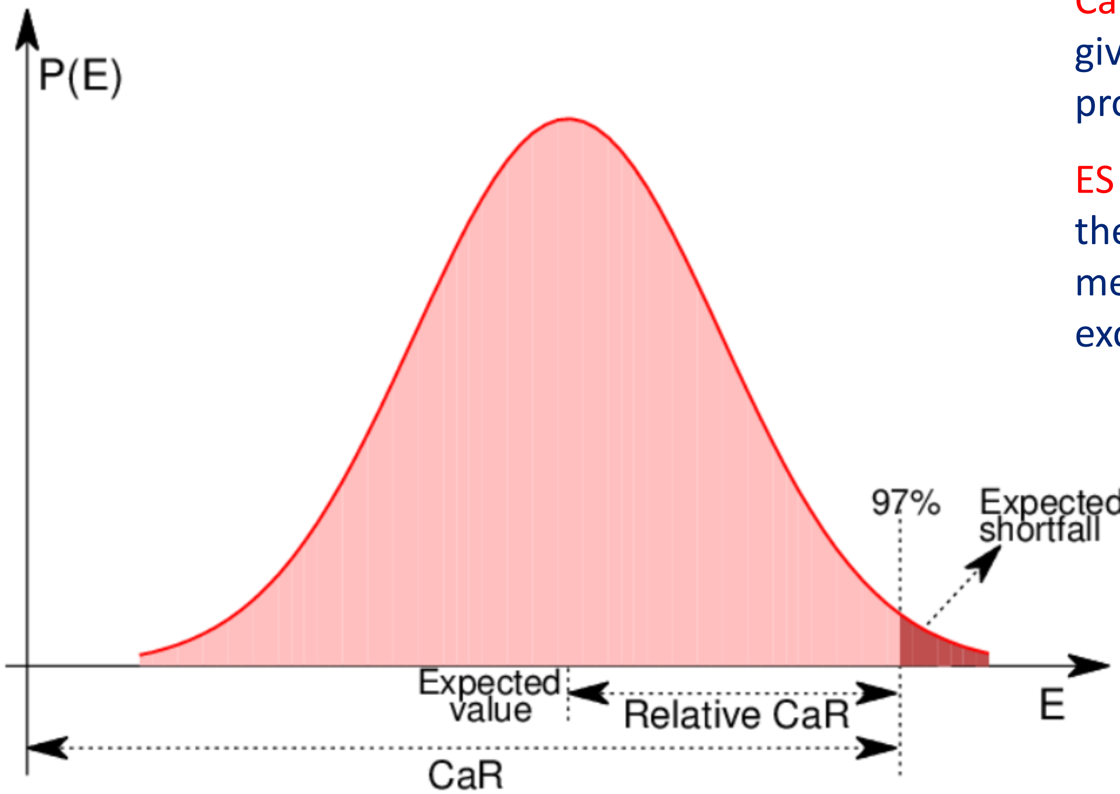
# Phase 2-3 …and the risk variable…

The generation of a large number of interest rates scenarios (our only risk factors), makes possible to estimate the probability distribution **P** of the ESA2010 growth rate.




CaR (Cost at Risk): cost growth rate of a given portfolio that, with a given probability *p*, cannot be exceeded.

ES (Expected Shortfall): expected value of the cost growth rate if a given risk measure (i.e., the CaR measure) is exceeded.

Average CaR values can be seen as cost measures.

The Standard Deviation or the Relative CaR (or the ES) can be seen as risk measures.

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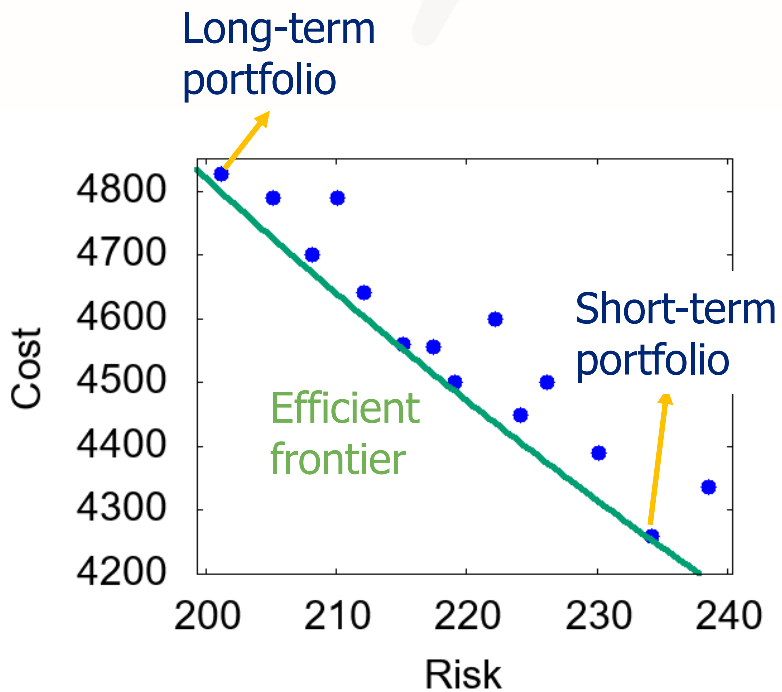
# Phase 2-3 …getting the efficient frontier

SAPE allows spotting the efficient frontier, where the trade-off between cost and risk should be searched, regardless of the yield curves shape.




The cost function is a concise metrics of the distribution function (*e.g.*, the average value) whereas the risk function gives a measure of the fluctuations (*e.g.*, the standard deviation or the relative CaR)

Each point represents a possible issuance portfolio.

# Phase 4 - Other Analysis

- Accounting reports that consider each feature of the financial instruments included in both the outstanding portfolio and future issuances of domestic, derivative and foreign currency securities;
- Sensitive analysis for the evaluation of the response to interest rates shocks considering both outstanding and future issuances;
- Dynamics of the evolution of the minimum and maximum costs of a set of possible portfolios of public debt securities.

# Phase 4 - CVA modelling

- A Credit Support Annex (CSA) aims at mitigating the credit risk of OTC derivative transactions by defining the conditions under which collateral is posted between the counterparties. Italian Treasury adopted a non-standard collateral framework to reduce the credit risk.

- The measure of this reduction is given by the Credit Valuation Adjustment (CVA), which is the difference between the value of a risk–free portfolio and the value considering a counterparty's default:

$$\text{CVA} = \text{lgd} \cdot \int_0^T E^Q[D(t) \cdot \text{EE} \mid t = \tau]\, dDP(0,t)$$

loss given default: $1 - rr$
$rr$ is the recovery rate
from the market

$$\begin{matrix} mtm_{00} & \cdots & mtm_{0n} \\ \vdots & \ddots & \vdots \\ mtm_{m0} & \cdots & mtm_{mn} \end{matrix}$$

mtm from 1-factor Hull-White
model with CSA constraints
(Expected Exposure EE)

default probabilities (DP) from
Credit Default Swap (CDS)
using moral hazard model

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# Main Features of the Software

- Time consuming parts (*i.e.*, simulations of many scenarios for ESA2010 cost evaluation of multiple portfolios) are carried out using high-performance computing techniques
- Software may run in background (for large scale simulations) or in interactive mode (with a GUI) for less demanding accounting tasks.
- Highly portable: run on Windows, Mac OS X, Linux
- Custom database to manage historical issuances, indexes and input/output files

# Summary and future directions

- SAPE is a complete decision support tool for the management of public debt securities
  - Integrating generation of term structure of interest rates, cost-risk analysis, CVA calculation
  - Can be used also as an accounting tool
- Underlying philosophy of constant research to enhance each component of the debt management process
- Currently investigating:
  - Foreign currency debt issuances and currency risk management
  - Alternative estimation methods for scenario generation
  - Robust Cost-Risk measures