OUTLINE OF RISK SCENARIO GENERATION PROCESS OF THE B3 CLEARINGHOUSE

Risk Management Department

Risk Modeling Division

INDEX

PRESENTATION

Margin requirement for the B3 Clearinghouse participants is calculated using the Close-Out Risk Evaluation (CORE) methodology. CORE is a risk measure that takes into consideration three types of risk:

- Market;
- Liquidity;
- Cash flow.

The market risk (losses resulting from price variation) is represented in CORE by a combination of **10,000 scenarios** for future prices of traded instruments and collateral across a certain risk horizon (from one to ten days). The scenarios have the important role of determining **which diversification benefits will be allowed by the Clearinghouse**.

This present document sets out the main aspects of the scenario generation methodology. It is divided into four sections. The first presents the basic concepts of scenario generation. The three following sections go into some detail, although non-exhaustive, about the three scenario generation strategies employed.

Registration of versions and changes

Version	Item Modified	Modification	Motive	Date
2	NA	NA	NA	Aug. 28, 2017
3	1; 2	Number of scenarios; Period contemplated by historical scenarios	Changes in historical scenarios	Dec. 28, 2018
4	1; 2	Number of scenarios; Period contemplated by historical scenarios	Changes in historical scenarios	Apri. 12, 2019
5	1; 2	Number of scenarios; Period contemplated by historical scenarios	Changes in historical scenarios	Jan. 08, 2020
6	1; 2	Number of scenarios; Period contemplated by historical scenarios	Changes in historical scenarios	Aug. 03, 2020
7	1; 2	Number of scenarios; Period contemplated by historical scenarios	Changes in historical scenarios	Mar. 26, 2021
8	1; 2; 4	Number of scenarios; Period contemplated by historical scenarios; Prospective scenarios paths of protection in different risk horizons	Change in historical and prospective scenarios	Jun. 29, 2022
9	1; 4	Number of scenarios; Prospective scenarios paths of protection in different risk horizons	Change in prospective scenarios	Sep. 8, 2022
10	1; 2	Number of scenarios; Period contemplated by historical scenarios	Changes in historical scenarios	Dec. 21, 2023

1. INTRODUCTION

The price scenarios for the instruments and collaterals used for calculating the **margin requirement** on a particular day result from the **full-valuation pricing** of the instruments on the basis of simulated values for their risk factor prices. The risk factor price simulation is performed by applying **shocks** (variations) to the closing values from the previous business day.

Consider the first maturity of the USDBRL futures contract as an example. It has exposure to three risk factors: the USDBRL spot rate, the local interest rate denominated in Brazilian Reais and the interest rate denominated in US Dollars (Cupom Cambial) of the same maturity. This instrument's price in the scenarios on day T result from the full-valuation pricing of the instrument through scenarios for the variations of these factors applied to their respective T-1 closing prices.

Risk factor mapping for all traded instruments and for securities accepted as collateral is available on the B3 website.

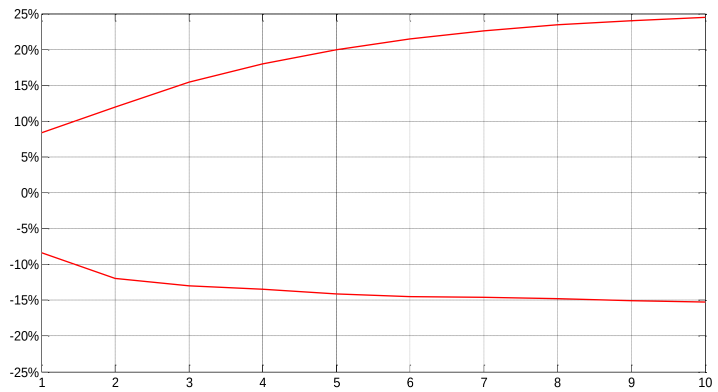
The **Market Risk Technical Committee** is the B3's governing body responsible for determining **scenarios for the risk factor price variations**. The risk management team of **specialists prospectively** determines the scenarios, fixing a 99.96% confidence level considering fat-tailed distributions. Scenarios are constructed taking into account the portfolio risk decomposition into the risk factors' individual risks and the joint movement risk of these factors.

The individual risk of a risk factor is determined by prospective minimum and maximum variations that are set by the Market Risk Technical Committee, given the 99.96% confidence level for **each risk horizon**. These caps and floors limit the factor's price variations in any scenario. For this reason, these variations constitute an **envelope** for the risk factor shocks. Two risk envelope scenarios are associated to each risk factor.

Figure 1 shows the two envelopes for a risk factor whose shock is a price percentage variation. For example, in ten days the largest positive shock allowed is 25% and largest negative one is -15%.

Consider a long position in a futures contract mapped in a single risk factor. Then suppose that the position is small given the liquidity available to settle it. If the envelope of this risk factor were that of Figure 1, the margin requirement would be determined by its two-day negative fluctuation: -12%.

Figure 1: Risk factor envelopes – risk horizon (day) x accumulated risk percentage



If there is a large enough historical sample for a risk factor, quantiles are estimated for the 99.96% confidence level using different univariate distributions with fat and asymmetric tails. These quantiles are inputs for the Market Risk Technical Committee's decision about this risk factor's envelope.

We define a **risk scenario** as being a combination of **shocks for all risk factors** over a ten-day price path. A scenario for one risk factor is thus represented by a ten-line column vector and a scenario for all the N risk factors, is represented by a matrix of ten lines and N columns. Each scenario has its own joint movement risk.

CORE uses 10,000 scenarios. The set of 10,000 scenarios, therefore, can be understood as a "folder" of 10,000 "files", with each "file" being a matrix with ten lines and N columns.

Consider again the example of the USDBRL futures contract. The initial margin charged on this long futures position is defined by the worst possible joint movement of its three risk factors returns. In other words, the margin requirement is defined by the worst joint price variation of its risk factors obtained from the 10,000 scenarios: a depreciation of the USDBRL spot rate, a decrease in the interest rate denominated in US Dollars (Cupom Cambial) for the same maturity and an increase in local interest rate denominated in Brazilian Reais of the same maturity.

Three **different** and **complementary** generation strategies are employed for scenario generation:

A. **Historical** (4,803):
   - Scenarios with IDs between 1,232 and 6,035;
   - A backtesting process within the margin model;
   - The historical sample is a meaningful representation of future realizations of risk factor price variation;
   - Historical simulation comprising all the rolling windows of one to ten days price variations between January 2004 and May 2023.

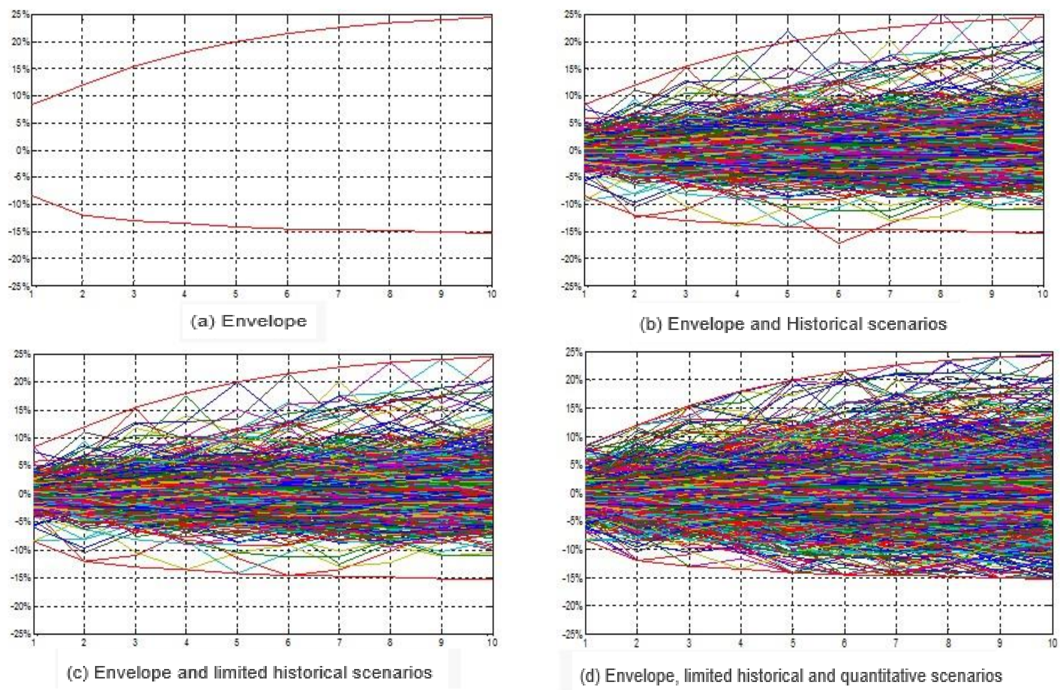
B. **Quantitative** (3,962):
   - Scenarios with IDs between6,036 and 9,997;
   - Seek to increase plausible shocks coverage using Monte Carlo simulations;
   - Shocks that could have happened but have not necessarily occurred in the sample;
   - Shocks are simulated from quantitative models that are estimated from historical data and that seek to incorporate stylized facts documented in the finance literature.

C. **Prospective** (1,232)
   - Scenarios with IDs between 1 and 1,232;
   - Seek to raise the degree of the Clearinghouse's protection against decreases in margin requirement generated by the benefits of spurious diversification for relevant positions and risk factors;
   - Break up historical correlations;
   - Introduce plausible events that did not occur in the sample;
   - Six subtypes of prospective scenarios.

The complementary nature of the three strategies for scenario generation is illustrated by the increased coverage for a risk factor's plausible events, as shown in Figure 2.

Figure 2.b shows the envelopes and the historical scenarios. Each line represents a ten-day price path constructed as the accumulated returns from one to ten days on a specific date. All of the one to ten day rolling windows present in the sample are shown. Figure 2.c presents the same scenarios as 2.b now limited by the envelopes. Figure 2.d adds the quantitative scenarios to the historical scenarios. As expected, the scenarios simulated from quantitative models raise the tail coverage by adding scenarios to areas within the envelopes that were thinly populated by the historical scenarios. It is expected that historical scenarios alone will not fully cover the area between the envelopes given the limited available sample and the high confidence level chosen for the envelopes.

Figure 2: Types of scenarios for a risk factor



All three types of scenario generation strategies will be covered in greater detail in the following sections.

2. HISTORICAL SCENARIOS

The full set of historical scenarios employed by CORE encompasses all paths of one to ten-day of accumulated returns observed in the **sample** that begins on January 2004 and ends on May 2023, totaling 4,803 scenarios for each risk factor.

To capture the **historical joint movement** among the different risk factors, there can be no gaps in the time series of risk factor prices. In other words, all risk factors must have recorded prices on all of the dates of the sample. In practice, however, this requirement is not always met. The launch of new instruments and lack of liquidity are two of the reasons for missing values in the time series sample.

To get around this problem, the specialized literature offers quantitative methods for the treatment of missing values. Generally speaking, these methods use returns on securities that have similar behavior to that of the risk factor that needs to have its time series completed. This problem is particularly important for equities: new shares are routinely issued through IPOs and the liquidity among them varies a lot.

The missing data can be classified as either randomic (for example, lack of liquidity) or deterministic (for example, prior to an IPO).

In the case of random missing values, the **Variational Bayesian Principal Component Analysis** (VBPCA) algorithm is employed for determination of the missing values. This method belongs to the class of algorithms known as PCA probabilistic models (Tipping and Bishop, 1999).

In the case of a deterministic missing values, two methods are used to fill the gaps in the time series of returns.

The first method used is the **factor model for equities** described in Section 3. This model explains a shares' return as a function of common and idiosyncratic factor returns. The time series of common factor returns are used to fill the missing values. The constructed returns are adjusted in accordance with the volatility observed for the stock's actual return in the period. Since the model is estimated from 2007 onwards, its common factors returns may be used only after that date.

For the period of the sample between January 2002 and December 2006, **conditional resampling** is used. This procedure has three steps:

- First get the return observed for Ibovespa index on the date on which there are missing values for one or more stocks;
- After this, the date is sought on which Ibovespa's return was observed at the closest value to the observation previously recorded and on which returns were observed for all the stocks with missing values.
- The returns observed for the stocks are then repeated on the date of the missing values.

Stock indices' return time series are constructed from the returns of the single name stocks that make up the index baskets based on each index composition at the most recent dates available. This is done once the time series for the stocks are adjusted for all missing values.

3. QUANTITATIVE SCENARIOS

Monte Carlo simulations based on quantitative models estimated from the historical data generate the risk factor shocks in quantitative scenarios[1]. These models are selected to capture the main characteristics of financial securities and portfolio returns (fat tails, asymmetry and persistent volatility, for example).

The quantitative models incorporate the intertemporal dependence structure of the ten risk horizons with AR-GARCH processes. The error term of the AR-GARCH model is simulated independently in the risk horizons in the Monte Carlo simulation.

If the joint movement of a group of risk factors is strongly **justifiable**, it will be modeled and the shocks for the risk factors in that group will be generated **jointly**. Otherwise, the risk factors' shocks will be simulated **independently**.

The joint movement of interest rates of differing maturities in the same Term Structure of Interest Rate (TSIR), equities with good liquidity and exchange rates, is justified theoretically and empirically. In these cases, there is joint movement modeling through a **grouped-t copula**, which shall be discussed later.

The Clearinghouse is exposed to five TSIRs:

- Nominal interest rates denominated in Brazilian Reais and traded in Brazil;
- Nominal interest rates denominated in US Dollars and traded in Brazil (Cupom Cambial);
- Real interest rates denominated in Brazilian Reals and traded in Brazil;
- Nominal interest rates denominated in US Dollars and traded in the US (Treasury Bills and Bonds);
- Nominal interest rates denominated in euro and traded in Germany (Bunds);

Each TSIR is modeled by a variant of the **Dynamic Nelson and Siegel Model** proposed by Christensen, Diebold and Rudebusch (2011). The model decomposes the interest rate as a function of maturity τ in accordance with equation (1):

$$y_t(\tau) = l_t + s_{1t}\left(\frac{1-e^{\lambda_{1t}\tau}}{\lambda_{1t}\tau}\right) + s_{2t}\left(\frac{1-e^{\lambda_{2t}\tau}}{\lambda_{2t}\tau}\right) + c_{1t}\left(\frac{1-e^{\lambda_{1t}\tau}}{\lambda_{1t}\tau} - e^{\lambda_{1t}\tau}\right) + c_{2t}\left(\frac{1-e^{\lambda_{2t}\tau}}{\lambda_{2t}\tau} - e^{\lambda_{2t}\tau}\right) \qquad (1)$$

Thus, the interest rates of the different maturities belonging to the same TSIR are determined by five common factors:

- Level (l_t);
- Two slopes: short and long terms (s_{1t}, s_{2t});
- Two curvatures: short and long terms (c_{1t}, c_{2t}).

[1] The parameters of the models may be altered by the Technical CCP Risk Committee in relation to those estimated to deal with a regime shifts in the returns of the risk factors. That is, situations in which the regime observed in historical returns is no longer valid for the current or near future returns.

The structure of intertemporal dependencies of the common factors is modeled as a Vector Autoregression (VAR) model in the state equation of a state space model that has equation (1) as its measurement equation. The error of this VAR is simulated for each of the ten risk horizons independently.

To assure **break-even inflation** is consistently modeled, the term structure of real and nominal interest rates in Brazil share the same slopes and curvatures, although different levels are allowed.

The original Christensen, Diebold and Rudebusch (2011) model is implemented assuming that the variations of the common factors follow a multivariate normal distribution. For scenario generation, it was opted to implement it with an alteration: the common factors follow asymmetric univariate distributions with fat tails interlinked by a t-copula[2].

Single name stocks are divided into two mutually exclusive groups. The first group is composed of stocks with low liquidity and subject to poor price formation process. Time series of returns from stocks in this group cannot be used for assessing joint movement with other stocks. The returns on stocks in this group are modeled by asymmetric univariate distributions with fat tails and the scenarios generated for these stocks are simulated independently.

The second group is composed of single name stocks with good liquidity (approximately 140 names) and informative time series of price returns. These stocks are modeled by a factor model. The factor model decomposes the return of each stock into factors common to all the stocks in this group and into an idiosyncratic factor unique to each stock.

Equation (2) decomposes the return of stock n denominated in Brazilian Reais in k common factors r_{f_k} and one idiosyncratic factor ε_n.

$$r_{n,t}^{BRL} = r_{f\,m,t} + \sum_{k=1}^{K} \beta_{n,k,t} r_{f\,k,t} + \varepsilon_{n,t} \qquad (2)$$

where $\beta_{n,k}$ is the exposure (or beta) of stock n to common factor k. There are four common factors in the model:

- Market;
- Sectors;
- Liquidity;
- Government influence (shareholder control, regulation, public concession and none).

The factor model above is estimated in cross-section. The exposure values to each common factor are known ex-ante and the factor returns are estimated for each day on the historical sample. The time series of factor returns are constructed from stacking all the estimated factor returns.

[2] The Christensen, Diebold and Rudebusch original model (2011) guarantees that there are no arbitrage opportunities. The implementation of this model with t-distributions means this is no longer true. The loss of this guarantee does not generate undesirable effects as the scenarios are used in risk measurement.

The common and idiosyncratic factor returns are modeled by asymmetric univariate distributions with fat tails and dependencies are described by a t-copula. Intertemporal dependencies are described by AR-GARCH models for each factor and the model errors are simulated independently for each risk horizon.

The implied volatility shocks result from the volatility shocks to the factors in the factor model, assuming independence among the idiosyncratic factors and between these and the common factors, in accordance with equation (3).

$$var\left(r_{n,t}^{BRL}\right) = \sum_{k=1}^{K} \beta_{n,k,t}^{2}\, var\left(r_{f\,k,t}\right) + 2\sum_{k=1}^{K-1}\sum_{j=k+1}^{K} \beta_{n,j,t}\beta_{n,k,t}\,\rho_{f_j,f_k}\sqrt{var\left(r_{f\,j,t}\right)}\sqrt{var\left(r_{f\,k,t}\right)} + var\left(\varepsilon_{n,t}\right) \quad (3)$$

where ρ_{f_j,f_k} is the correlation between common factor returns j and k.

Two independent factor models are employed in the risk decomposition of equity returns, one for local Brazilian stocks and another for foreign stocks.

Joint movement among **Exchange rates and their implied volatilities** is modeled by t-copula.

As previously discussed in this section, each risk factor group listed below has its interdependence structure modeled by a t-copula:

- Common factors of the factor model for Brazilian equities;
- Common factors of the factor model for foreign equities;
- Common factors of the BRL-denominated local nominal TSIR;
- Common factors of the USD-denominated local nominal TSIR;
- Common factors of the local real TSIR;
- Common factors of the US nominal TSIR;
- Common factors of the German nominal TSIR;
- Exchange rates and their implied volatilities.

The joint movement between all the common factors mentioned above is modeled through a **Grouped T-copula**. This modelling strategy allows for the joint movement **between** the eight groups above to be implicitly modeled whilst preserving the joint movement **within** each one of the groups. The Grouped T-copula can be understood as a combination of different copulas connected by the same correlation matrix.

For each risk horizon, the shocks are generated by Monte Carlo simulation following the steps below:

P1. The Grouped T-copula simulates the shocks to the common factors of equities, TSIRs, of the exchange rates and their implied volatilities;

P2. For each TSIR, the interest rate shocks result from the shocks to the common factors of the factor model for the TSIR simulated in P1 transformed by equation (1) and by the VAR model;

P3. The shocks to the idiosyncratic factors of the factor models for equities result from independent draws of the respective univariate distributions transformed by the respective AR-GARCH;

P4. The simulated returns of stocks that are eligible to be explained by the common factors in the equities factor model are calculated by equation (2), using the shocks calculated in P1 and P3;

P5. Returns of the stocks that are not explained by the common factors in the factor models result from independent draws of the respective univariate distributions transformed by the respective AR-GARCH;

P6. Putting together P4 and P5, simulated returns of equity indices and ETFs are calculated;

P7. The simulated shocks to implied volatilities of stocks derive from the variation of the volatilities of the common and idiosyncratic factors in accordance with the equation (3). The factor volatilities are simulated via the previously estimated AR-GARCH models.

Joint movement modeling and its simulation guarantee, by construction, consistency among the risk factor returns and the traded instruments and pledged collateral. In particular, the consistency among simulated stock returns, equity-indices returns and implied volatility shocks is guaranteed.

4. PROSPECTIVE SCENARIOS

The prospective scenarios seek to generate severe losses for the most common positions, whether directional or relative, and for the most relevant risk factors. Prospective scenarios need not be limited to observed joint movement and will cover movement between risk factors that is not registered in the historical sample. Not all risk factors are covered by these scenarios.

There are six prospective scenario subtypes. The first two contemplate the most relevant risk factors from all asset classes. The third is dedicated to joint movement between implied volatilities used in option pricing and their underlying securities prices. The next three are dedicated solely to equity risk factors.

The risk factor shocks generated for each prospective scenario are determined by the percentage consumption of the risk factors envelope scenarios. Percentage consumption indicates the direction and magnitude of the risk factor variation in the scenario.

4.1 DIRECTIONAL POSITIONS IN RELEVANT FACTORS

This combination of scenarios seeks to generate severe losses in directional positions in the risk factors that are most relevant for the Clearinghouse. The scenarios result from the combination of negative shocks and positive shocks to risk factors in the following risk factor groups:

a) USDBRL spot exchange rate;
b) Local nominal and real interest rates;
c) Local USD-denominated interest rate (Cupom Cambial);
d) Commodities;
e) Stocks (conditioned on the factor model for stocks).

All of the possible combinations of positive and negative shocks to the risk factor groups are generated using each one of the (a), (b), (c) or (e) groups as a reference risk factor:

- The shocks to the reference factor are always their respective positive or negative **envelopes**;
- The shocks to the other risk factors that are in accordance with the joint movement that is regularly observed between factor and reference factor are their respective negative or positive **envelopes**;
- The shocks applied to the risk factors that are not in accordance with the expected joint movement between factor and reference factor are **fractions of their respective envelopes** (currently, 50%).

The shocks to stocks eligible to be in the factor model are determined by the shocks applied to the common factors of the factor model:

- Shocks applied to the stocks risk factors are **fractions of their envelopes**:
  - Market factor: positive and negative shocks defined by the **fraction of the envelope scenario**
  - Sector factors: shocks are **fractions of their respective envelopes** (currently, 11%)
- Shocks applied to the stocks risk factors are their **envelopes:**
  - Market factor: positive and negative shocks defined by the **envelope** scenario
  - Sector factors: shocks are **fractions of their respective envelopes** (currently, 22%)

The shocks to commodities and stocks that are not eligible to the factor model are their respective positive or negative **envelopes**. As the envelope scenarios (in basis points) of different maturities of the same TSIR have different values, this subtype of prospective scenarios will generate movements on the level, slope and curvature of the term structure.

All the possible negative and positive combinations of the five groups of risk factors above result in 60 prospective scenarios. Table 1 below represents the joint movement of some of these scenarios. Please note that the sign of the shocks to the stocks are always the same in the scenarios.

Table 1: Joint movement among risk factors in the scenarios of the first subtype

Scenarios	Percentage of Risk Factor's Envelopes						
	BRL/USD	US Dollar Spread	Nominal and Real Term Structure	Commodities	Stock factor model: Market factor	Stock factor model: Sector Model	Stocks not eligible to model
1	+ 100%	+ 100%	+ 100%	+ 100%	- 100%	-22%	- 100%
2	+ 100%	+ 100%	+ 100%	+ 100%	+ 50%	+ 11%	+ 100%
3	+ 100%	- 50%	+ 100%	+ 100%	- 100%	-22%	- 100%
4	+ 100%	- 50%	+ 100%	+ 100%	+ 50%	+ 11%	+ 100%
...	...	...	...	...	...	...	...
60	- 50%	- 50%	- 50%	- 100%	- 100%	-22%	- 100%

The shocks to the implied volatilities in this subtype of prospective scenarios are determined by the shocks to the respective underlying assets in accordance with the joint movement that is normally expected. In other words, the sign of the **envelope** scenario used for the implied volatility **is the same** as the sign of the variation in the **risk premium** of the underlying asset. Examples: if the shock to the USDBRL spot rate is the positive envelope scenario for USDBRL spot (risk premium rises), its implied volatility shock will also be the positive envelope scenario; if the Ibovespa shock is its positive envelope scenario (risk premium falls), its implied volatility shock will be its negative envelope scenario.

4.2 POSITIONS IN RELEVANT FACTORS

These scenarios result from two modifications to the scenarios of the first subtype:

- Stocks (and their implied volatilities) that do not belong to the two most relevant sectors are not stressed;
- Stocks of the two most relevant sectors may have shocks with opposite signs.

All the possible combinations of positive and negative shocks for the six risk factor groups below result in 192 scenarios:

a) USDBRL spot exchange rate;
b) Local nominal and real interest rates;
c) Local USD-denominated interest rate (Cupom Cambial);

d) Commodities;
e) Stocks in the most relevant sector for the Clearinghouse;
f) Stocks in the second most relevant sector for the Clearinghouse.

In order to maintain plausibility, if the shocks to the stocks of one sector are its positive (negative) **envelope scenario**, the shocks to the stocks in the other sector will be a **fraction of their** negative (positive) **envelope scenario**.

4.3 UNDERLYING ASSETS AND IMPLIED VOLATILITIES

These scenarios seek to stress the joint movement between the price variation of the underlying asset and the shock to its respective implied volatility.

The sign of the shock applied to the implied volatility is **opposite** to the expected sign of the variation in the **risk premium** component of the underlying asset's return. For example, in the scenario in which the shock to the USDBRL spot is its positive **envelope scenario**, its implied volatility will fall in accordance with its negative **envelope scenario**.

The scenarios are generated by the combinations of the negative and positive shocks of the following risk factors groups:

a) USDBRL spot exchange rate;
b) Local nominal and real interest rates;
c) Local USD-denominated interest rate (Cupom Cambial);
d) Commodities.
e) Stocks (conditioned on the factor model for stocks);

There are two different scenarios in this subtype of the prospective scenarios. In the first, all of the risk factors of the options' underlying assets of the (a), (b), (c) and (d) groups are subject to shocks the same as those of their positive envelopes and the risk factors of the options' underlying assets of the (e) group are subject to shocks the same as those of their negative envelopes. The shocks applied to their respective implied volatilities are the same as those of their envelopes opposite to what would be expected given the risk premium component. In the second, all of the risk factors of the options' underlying assets of the (a), (b), (c) and (d) groups are subject to shocks the same as those of their negative envelopes and the risk factors of the options' underlying assets of the (e) group are subject to shocks the same as those of their positive envelopes. The shocks applied to their respective implied volatilities are the same as those of their envelopes opposite to what would be expected given the risk premium component.

4.4 DIRECTIONAL AND RELATIVE VALUE POSITIONS IN FIVE RELEVANT SECTORS

These scenarios seek to generate severe losses in portfolios containing **directional and relative value positions** of stocks belonging to the five most relevant **sectors** for the Clearinghouse.

All the combinations of positive and negative shocks for the five sectors result in 62 scenarios.

To maintain the plausibility of the scenarios in which there are price movements among different sectors, the determination of the stocks shocks' size follows the procedure below:

i. Each of the five sectors takes a pivotal position;

ii. For the **positive** price shock scenarios, the shocks for stocks in the pivotal sector are its **positive envelope scenarios**:

   a. Stocks in the sectors whose prices **rise** will receive shocks equivalent to their **envelopes**;

   b. Stocks in the sectors whose prices fall will receive shocks equivalent to **fractions of the envelopes**;

iii. For **negative** price scenarios, the shocks to stocks in the pivotal sector are equivalent to its **negative envelopes**:

   a. Stocks in the sectors whose prices rise will receive shocks equivalent to **fractions of the envelopes**;

   b. Stocks in sectors whose prices **fall** will receive shocks equivalent to their **envelopes**;

The shocks to stocks outside of the five sectors are null and shocks to equity indices and ETFs are defined by the shocks to the stocks in their composition. The relationship between the implied volatility shocks and the variations of their underlying assets is the same as the one observed in the scenarios in 4.1.

4.5 RELATIVE VALUE POSITIONS IN RELEVANT COMPANIES

This combination of 180 scenarios seeks to generate severe losses for portfolios with **relative value positions** made up of single name stocks from ten different relevant **companies** for the Clearinghouse.

Each scenario aims to generate a severe loss for one relative value position comprised of two stocks: long (short) in a stock issued by one of the top ten companies versus short (long) in a stock issued by another of the companies.

In order to maintain the plausibility of relative price movements, when the stock of one company experiences a shock that is the same as its **envelope** (positive or negative), the stock of the other company of the pair experience a shock that is a **fraction of its envelope** (negative or positive).

The shocks to the rest of the stocks are null and the equity indices and ETFs are defined by the shocks to the stocks in their composition. The relationship between shocks to the implied volatilities and the variations of their underlying assets is the same as in 4.1.

4.6 RISK FACTOR PROTECTION IN DIFFERENT RISK HORIZONS

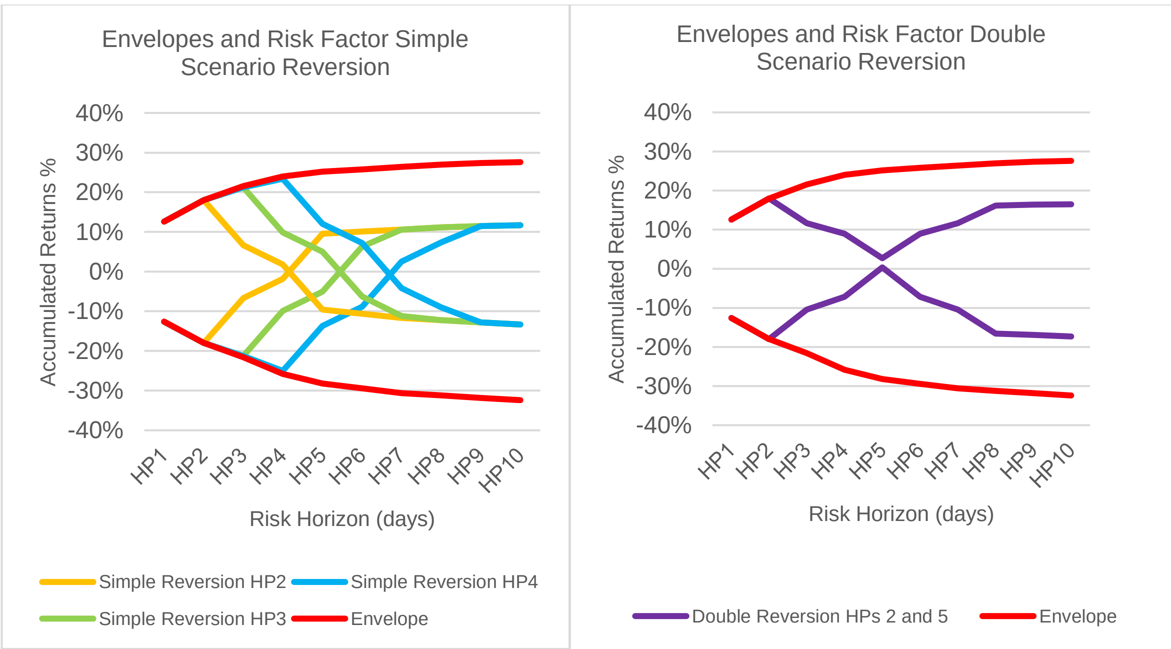
This combination of scenarios seeks to stress plausibly the efficiency of hedges: the same risk factor traded in different instruments with different closeout periods.

For example, an investor can protect their long position in USDBRL futures with a short position in options on USDBRL futures. As options are not as liquid as futures, their closeout period comes after that for futures. If after a shock is observed there is no plausible trajectory for the USDBRL spot price that implies reversion of the price path, the protection will always be at its most efficient.

Each risk factor has 104 trajectories, with the following possible constructions:

- Simple Trajectory Reversion (seventy-eight trajectories): each trajectory begins with a sharp increase or decrease in price at the two-, three-, or four-day risk horizon and rapidly reverses its direction until the five-, six-, or seven-day risk horizon days, respectively. From then on, it continues to vary in the reversed direction at a slower pace until the last day of the risk horizon.
- Dual Trajectory Reversion (twenty-six trajectories): Each trajectory begins with a sharp increase or decrease in price over the two-day risk horizon and rapidly reverses its direction through the five-day risk horizon. From then on, it reverts back to the same direction as the beginning of the movement, varying until the last day of the risk horizon.

These scenarios are represented in Figures 4 and 5.



Envelopes and Risk Factor Scenario Reversion

All the risk factors of the following blocks are stressed:

a) USDBRL spot exchange rate;

b) Local nominal and real interest rates;

c) Local USD-denominated interest rate (Cupom Cambial);

d) Stocks.

The 736 scenarios of this subtype result from the combination of the eight reverse paths for the risk factors groups above, respecting the expected or unexpected joint movements among them. The relationship among the implied volatility shocks and the variations of their underlying assets is the same as the scenarios in 4.1

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