Stress test methodologies

Manual

Version 12.0 as of 25 March 2020

London Stock Exchange Group

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Foreword

In order to preserve market integrity in case of insolvencies even under the most extreme conditions, CC&G – following international best practices and in line with regulatory requirements[1] – gauges the appropriateness of its Default Funds through stress test simulations.

The amount of the Default Funds is indeed established in such a way that CC&G is able to ensure the stability of the guarantee system also in case of simultaneous members' defaults under stress conditions. CC&G has set the amount of the Default Fund in line with the Non-Collateralized Exposure of at least the first two most exposed Clearing Members. As a matter of fact, the number of "covered" Clearing Members is set at a higher and more conservative level (in order to cover at least the four largest Participants[2] on the Bond Section and the three largest Participants on the other Sections).

The stress tests are executed, at least on a daily basis, separately for the Equity and Equity Derivatives Section, for the Energy Derivatives Section, for the Agricultural Commodities Derivatives Section and for the Bonds Section.

This document describes the methodology used by CC&G to execute its stress tests, exposing the purposes and how the stress test Scenarios are defined for the different Sections.

1.0   Methodology

The stress tests executed by CC&G are intended to «gauging» the vulnerability – under extreme market circumstances – of its guarantee system in case of risk factors variations of exceptional magnitude – larger than those covered by the initial margining system – but nevertheless reasonably possible.

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[1] The mainly applicable regulations and guidelines for stress tests are listed below:

- EMIR (European Market Infrastructure Regulation): *Regulation (EU) No 648/2012 of The European Parliament and of The Council of 4 July 2012 on OTC derivatives, central counterparties and trade repositories*;
- RTS ESMA (Regulatory Technical Standards): Commission Delegated Regulation (EU) No 153/2013 of 19 December 2012 supplementing Regulation (EU) No 648/2012 of the European Parliament and of the Council with regard to regulatory technical standards on requirements for central counterparties;
- Principles issued by Committee on Payment and Settlement Systems (CPSS) and the Technical Committee of the International Organization of Securities Commissions (IOSCO).

[2] In the document "Participants" or "Clearing Members" refer to all the entities belonging to the same Banking Group.

The stress test methodology adopted by CC&G allows to evaluate the consequences of the hypothesized event, but does not provide any indication regarding the «probability» that the event itself may actually happen. Unlike the initial margins system – which bases itself on the definition and on the application of «confidence intervals» – stress testing, being based on extreme circumstances, only allows for a limited use of common statistical tools. It is as a matter of fact mainly based on common sense hypotheses and experience with the aim of providing a risk measure for stress Scenarios from time to time defined.

In order to limit the use of subjective hypotheses, it has been deemed appropriate to adopt, in performing stress tests, an Historical Scenario[3], which is, where necessary, duly integrated with an Hypothetical Scenario[4]. The adopted Scenarios are fully reexamined and revised – in line with the EMIR provisions – at least once a year.

2.0   Purpose

The purpose of the Stress Test is the determination – according to the stress scenario time to time applied – of the "Non Collateralized Exposure" (NCE) for each Clearing Member, that is the amount that the Participant would be required to deposit with CC&G as a consequence of the new (initial and variation) margin call after the hypothesized price variations. NCE is, in fact, the algebraic sum of the amounts needed to:

– *mark-to-the-market open positions at the post stress hypothesized values;* such amount[5] therefore represents the losses CC&G would suffer in case of instantaneous liquidation of the insolvent's positions;

– *re-establish guarantees for the same open positions*; such amount represents a new initial margin and it hence provides an indication of the further losses CC&G would suffer in case of adverse market movements during the liquidation of the insolvent's positions.

In order to determine a single NCE amount for each Direct Participant, the calculation is implemented considering the rule that allows, in case of insolvency, to use possible house account excesses to cover losses in the client account, and at the same time prohibiting the use of possible client account excesses to cover losses in the house account.

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[3]   The Historical Scenario evaluates the consequences of an event, equal to the largest shock registered in a sufficiently long time span on the financial markets considered. In this respect CC&G includes in its equities stress test, price variations occurred in September 2001. This approach has the advantage of being extremely intuitive and of being based on transparent hypotheses; on the other hand it assumes that future risks are equal to those occurred in the past. Furthermore in some cases it is impossible to define a Historical Scenario as in the cases of those securities, which do not have a sufficiently long time history or in those cases where the features of market and/or of the financial instruments have changed in time to the point of making meaningless the original assumptions.

[4]   The Hypothetical Scenario evaluates the consequences of a number of hypotheses, which are considered realistic under extreme circumstances although lacking of historical precedents in recent times. On one hand this approach is not dependent on the availability of historical data, on the other hand the results are strongly dependent from the evaluations – in some measure necessarily subjective – of the entity conducting the stress test.

[5] Variation Margins (for *futures*) or *Mark-to-Market* Margins (for *Cash* Instruments and Options).

The possibility for Members to set collateral, both cash and securities, for an amount equal to or bigger than those required by CC&G as initial margins is taken into account.

The Stress Tests are performed daily and separately for the Equities and Equities Derivatives Section, for the Bond Section, for the Energy Derivatives Section and for Agricultural Commodities Derivatives Section.

3.0 Equities and Equities Derivatives Section Scenarios

For the Equity and Derivatives Sections, two stress test Scenarios are hypothesised: a Downside Price Variation Scenario and an Upside Price Variation Scenario. The Scenarios are built up as described in the following paragraphs.

3.1. Downside Price Variation Scenario / Double Volatility

i. Equity Section

It is assumed that each security [6] undergoes a downside price variation equal to the worst between the following events:

a) the largest (both upside and downside) between 1-day, 2-days and 3-days price variation occurred over the available time series;

b) 1.20 times the «Applicable Margin Interval»[7] ;

c) 4 times[8] the Standard Deviation.

The hypotheses under a) and b) allow determining a hypothetical (i.e. not historically observed) price shock also for those securities which, having been only recently listed, have not yet shown an actual significant price variation.

It is worth mentioning that the use of a multiple of the Margin Interval – besides using a multiple of the standard deviation – allows accounting for the different behavior of securities – although having similar standard deviation values – towards extreme price variations (statistically expressed by the kurtosis); this is taken into account in determining the Margin Interval.

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[6] Shares, Convertible Bonds, Warrants, Closed Funds Shares and ETFs.

[7] The «Applicable Margin Interval» for derivatives and for underlying securities is equal to the Margin Interval used for the Derivatives Section, if calculated; otherwise equals to the Margin Interval used for the Equity Section.

[8] Such value indicates that, if price variation were normally distributed, the event being considered has a probability of occurrence no larger than 0.01%.

ii. *Equity Derivatives Section*

Regarding derivatives, the following approach is followed:

a) Equity Futures prices and FTMIB Index Futures[9] prices are assumed having a one-to-one price variation with their underlying;

b) FTMIB Index Dividend Futures prices are assumed having a price variation determined as above described for Equity cash;

c) Equity Options prices and FTMIB Index Options are recalcutated using the stressed price of their underlying and attributing to each option an implied volatility equal to twice the implied volatility of the option, having the corresponding moneyness (the so-called «sticky delta» approach)[10].

Figure 1 provides an example of the construction of the implied volatility curve for an options expiry.

Figure 1

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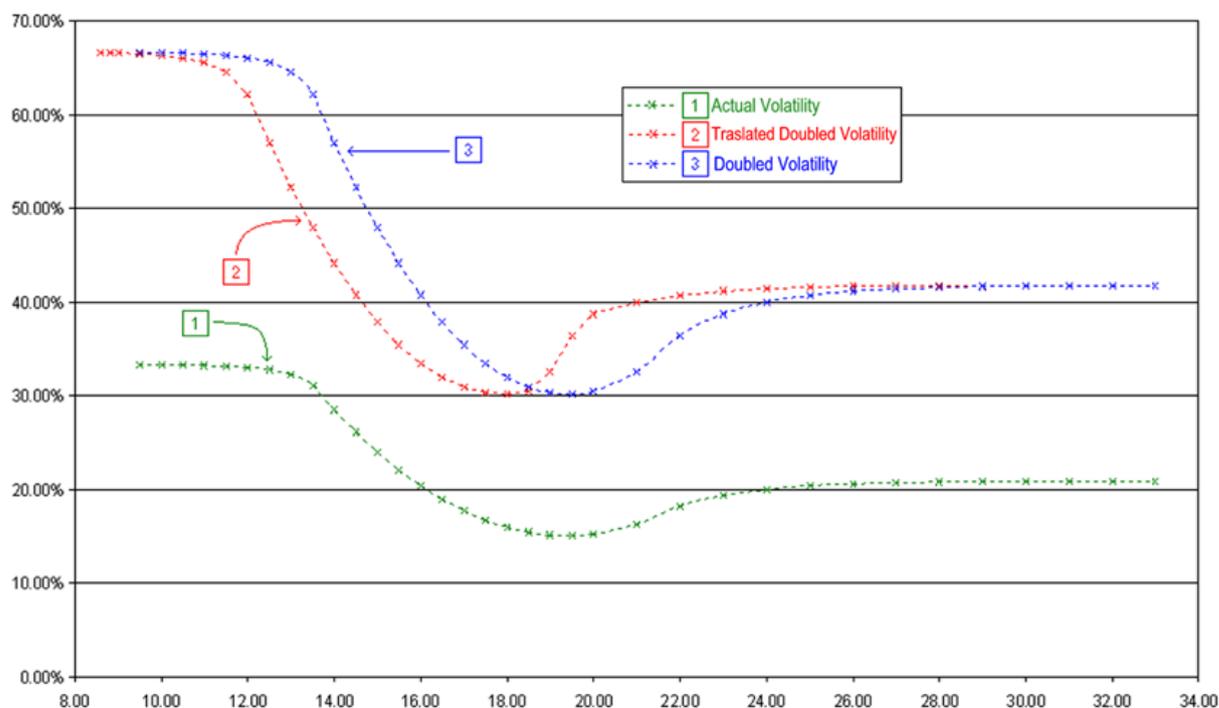
[9] The FTMIB index value is calculated on the basis of the new post stress values of its components.

[10] Example: It is assumed that XXX share drops −10% (from € 20.00 to € 18.00). The option Strike 20.00 (At-The-Money) has in reality an implied volatility of 16%; in the stress test the option Strike 18.00 (which in the stress test is At-The-Money) has an implied volatility of 32%.

3.2.   Upside Price Variation Scenario / Double Volatility

i.   Equity Section

It is assumed that each security has an upside price variation equal to the worst of the following events:

  a) the largest (both upside and downside) between 1-day, 2-days and 3-days price variation occurred over the available time;
  b) 1.20 times the size of the «Applicable Margin Interval»;
  c) 4 times the standard deviation.

The following table provides a summary of the hypotheses in the two Scenarios.

Hypotesis	Downside	Upside
a)	**largest** price variation (upside or downside) occurred over the whole available time series	**largest** price variation (upside or downside) occurred over the whole available time series
b)	**1.20 the value** of the «Applicable Margin Interval»	**1.20 the value** of the «Applicable Margin Interval»
c)	4 times the standard deviation	

ii.   Equity Derivatives Section

With regards to derivatives, the same approach as for the Downside Price Variation / double Volatility Scenario is applied.

3.3.   Downside Price Variation Scenario / Half Volatility

i.   Equity Section

This Scenario is equal to the "Downside Price Variation / Double Volatility Scenario".

ii.   Equities Derivatives Section

This scenario is similar to the "Downside Price Variation / Double Volatility Scenario", but Equity Options prices and FTMIB Index Options are recalculated using the stressed price of their underlying and attributing to each option an implied volatility equal to *half* the implied volatility of the option, having the corresponding moneyness.

3.4. Upside Price Variation Scenario / Half Volatility

i. Equity Section

This Scenario is equal to the "Upside Price Variation / Double Volatility Scenario".

ii. Equities Derivatives Section

This scenario is similar to the "Upside Price Variation / Double Volatility Scenario", but Equity Options prices and FTMIB Index Options are recalculated using the stressed price of their underlying and attributing to each option an implied volatility equal to *half* the implied volatility of the option, having the corresponding moneyness.

3.5. "Real-life price change" / Double Volatility

i. Equity Section

a. It is assumed that each security has a price variation equal, in magnitude, to the worst of the following events and in sign, to its real-life price change:
   1. the largest (both upside and downside) between 1-day, two days and three -days price variation actually occurred over the available time series;
   2. 1.20 times the size of the «Applicable Margin Interval», or;
   3. 4 times the standard deviation.

ii. Equities Derivatives Section

For the Equity Derivatives Section the same approach above described for the underlying is applied, considering the double volatility assumptions. The FTSE MIB index stressed price is recalculated on the basis of the new stressed value of its components.

3.6. "Real-life price change" / Half Volatility

i. Equity Section

b. It is assumed that each security has a price variation equal, in magnitude, to the worst of the following events and in sign, to its real-life price change:
   4. the largest (both upside and downside) between 1-day, two days and three -days price variation actually occurred over the available time series;
   5. 1.20 times the size of the «Applicable Margin Interval», or;
   6. 4 times the standard deviation.

ii. ***Equities Derivatives Section***

For the Equity Derivatives Section the same approach above described for the underlying is applied, considering the half volatility assumptions. The FTSE MIB index stressed price is recalculated on the basis of the new stressed value of its components.

3.7. "Extra-stress" / Double Volatility Scenario

i. **Equity Section**

  a. It is assumed that each security has a downside price variation equal to the worst of the following events:

      1. the largest (both upside and downside) between 1-day, two days and three -days price variation actually occurred over the available time;

      2. 1.20 times the size of the «Applicable Margin Interval», or;

      3. 4 times the standard deviation.

  b. It is assumed that the shares of the two most exposed banking groups in the Downside Price Variation / Double volatility Scenario have a downside price variation equal to 90% (considering a *recovery rate* of 10%).

ii. **Equities Derivatives Section**

For the Equities Derivatives Section the same approach as for the Downside Price Variation / Double Volatility Scenario is applied. The FTSE MIB index price variation is recalculated on the basis of the new stressed value of its components.

4.0 Energy Derivatives Section Scenarios

With regards to Energy Derivatives Section, two different types of stress test scenarios are foreseen: a Downside Price Variation Scenario and an Upside Price Variation Scenario. Such Scenarios are currently built as per the following description.

4.1. Downside Scenario

It is assumed that each energy futures – with the exception of the delivery positions – has a downside price variation equal to the worst of the following events:

a) the largest (both upside and downside) among 1-day, 2-days and 3-days price variation occurred in the whole time horizon available;

b) the size of the «Applicable Margin Interval»;

c) 4 times the standard deviation.

4.2. Upside Scenario

It is assumed that each security – with the exception of the delivery positions – has an upside price variation equal to the worst of the following events:

a) the largest (both upside and downside) among one-day, two-days and three-days price variation price variation actually occurred in the whole time horizon available;

b) 1.20 times the size of the «Applicable Margin Interval»;

c) 4 times the standard deviation.

Regarding the delivery position, it is assumed – in both scenarios – that the cash settlement is due to a difference between the last future price and the average monthly PUN[11] of the delivery month equal to 73%. That percentage is determined assuming that the average daily PUN – generally about € 60 – has a shock price to 500[12] for three days.

The following tables provide a summary of the hypotheses in the two Scenarios for the ordinary positions and for the delivery ones.

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[11] Single National Price (PUN – Prezzo Unico Nazionale).

[12] Hypothesis of highest price reached in an unexpected situation of crisis (e.g. power plant closure).

Ordinary Positions		
Hypotesis	**Downside**	**Upside**
a)	**largest** price variation (upside or downside) in the whole time horizon available	**largest** price variation (upside or downside) in the whole time horizon available
b)	the size of the Margin Interval	1.20 the size of the Margin Interval
c)	4 times the standard deviation	

Delivery Positions		
Hypotesis	**Downside**	**Upside**
a)	73%	

5.0   Bond Section Scenarios

For the Bond Section[13], three types of scenarios are hypothesized: Yield Increase Scenario, Yield Decrease Scenario and scenarios affecting to the slope of the yield curves. These scenarios will be applied only to government bonds, for which modified duration is available[14].

5.1.   Yield Decrease Scenario

   a) for each of the 45 vertices used in the construction of the Eurozone yield curve (from TN to 30Yrs), the largest yield variation is determined, defined as the highest value between the most extreme (both upside and downside) variations registered since January 2nd, 1999 (introduction of the Euro) and calculated taking into consideration a holding period[15] depending on the creditworthiness of the issuer evaluated according to the *Sovereign Risk Framework;*

   b) for each of the 25 vertices used in the construction of the Italian yield curve (from 3M to 30 yrs), the largest yield variation is determined, defined as the highest value

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[13] Stress Scenarios for Bond Section are used also for Collateral Stress tests (please refer to *Appendix - Stress scenarios for collateral*).
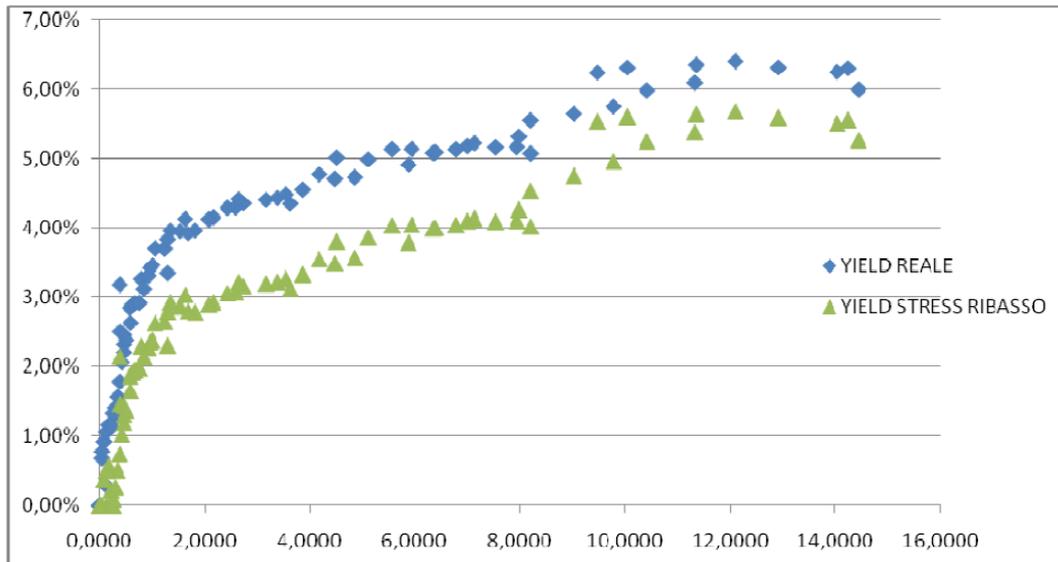
[14] For Corporate Bonds, Floating Rate bonds (CCTs) and Inflation Linked bonds, since Modified Duration is not available, a 1,2 times the Margin Interval shock will be applied.

[15] Holding period is set to a minimum of three days (i.e. 1-day, 2-days, 3-days yield variations are analyzed) and a maximum of five days.

between the most extreme upside, downside, one-day, two-days, … n-days yield variations registered since January 2nd, 1999 (introduction of the Euro). In order to obtain a grid of vertices consistent with the Eurozone yield curve, the largest yield variations for the missing vertices of the Italian zero coupon bonds curve are determined by linear interpolation of the previous and next available vertices;;

c) for each of the 25 vertices from 3 M to 30YRS the maximum value between the largest yield variation of the Eurozone zero coupon bonds curve and the largest yield variation of the Italian zero coupon bonds curve is determined;

d) for each government bond a yield variation, equal to the value resulting of the linear interpolation of the largest variation for the previous and next vertices to the duration of the bond (if the duration is not equal to any node), is determined;

e) for each government bond the new yield in the downside scenario is equal to the current yield minus the respective largest yield variation, determined as described at the preceding point;

f) the bond prices are recalculated on the basis of the above-mentioned downside yield curve scenario;

g) for each bond with a duration less than 9 months[16], the higher price resulting from the yield decrease scenario and the yield obtained by considering an upward price change equal to 1.2 times the margin interval (related to the class duration of the bond) is determined.

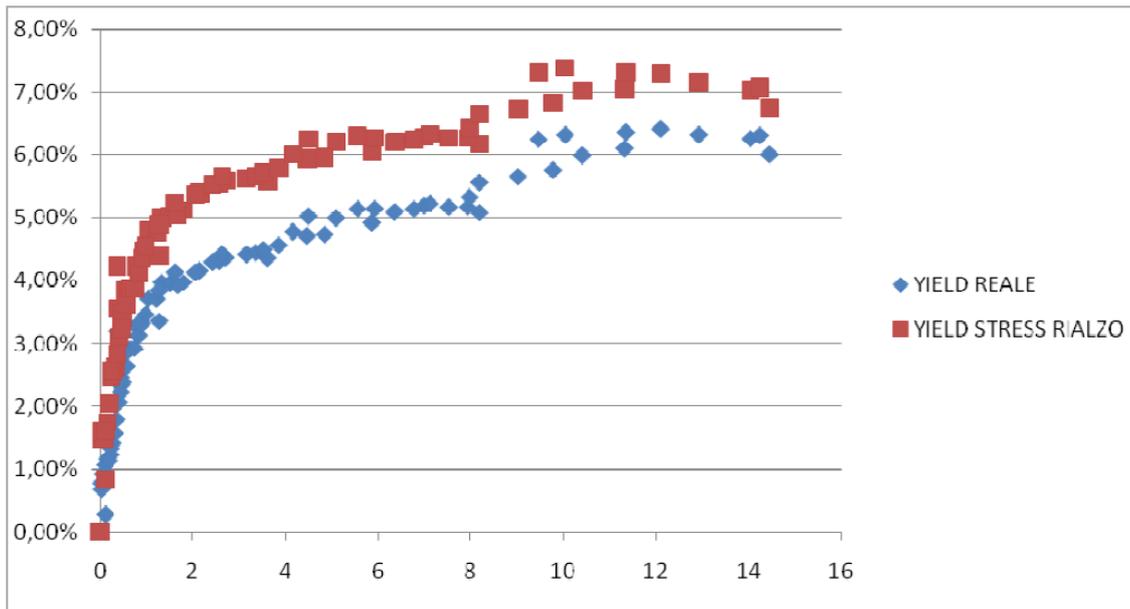**Figure 1: Yield Decrease Scenario**

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[16] For which only Eurozone Yield vertices are available.

For inflation linked bonds, floating rate bonds (CCT) and corporate bonds it is assumed an upside price variation equal to 1.20 the Margin Interval in force.

5.2.   Yield Increase Scenario

a) for each of the 45 vertices used in the construction of the Eurozone yield curve (from TN to 30Yrs), the largest yield variation is determined, defined as the highest value between the most extreme upside, downside variations registered since January 2nd, 1999 (introduction of the Euro) and calculated taking into consideration a holding period chosen on the basis of the creditworthiness of the issuer appraised according to the *Sovereign Risk Framework;*

b) for each of the 25 vertices used in the construction of the Italian yield curve (from 3M to 30 Yrs), the largest yield variation is determined, defined as the highest value between the most extreme upside, downside, one-day, two-days, … n-daysyield variations registered since January 2nd, 1999 (introduction of the Euro). In order to obtain a grid of vertices consistent with the Eurozone yield curve, the largest yield variations for the missing vertices of the Italian zero coupon bonds curve are determined by linear interpolation of the previous and next available vertices;;

c) for each of the 25 vertices from 3 M to 30YRS the maximum value between the largest yield variation of the Eurozone zero coupon bonds curve and the largest yield variation of the Italian zero coupon bonds curve is determined;

d) for each government bond a yield variation, equal to the value resulting of the linear interpolation of the largest variation for the previous and next vertices to the duration of the bond (if the duration is not equal to any node), is determined;

e) for each government bond the new yield in the upside scenario is equal to the current yield plus the respective largest yield variation as identified according to the previous point;

f) the bond prices are recalculated on the basis of the above-mentioned upside yield curve scenario;

g) for each bond with a duration less than 9 months, the lower price resulting from the yield increase scenario and the yield obtained by considering a downward price change equal to 1.2 times the margin interval (related to the class duration of the bond) is determined;

Figure 2: Yield Decrease Scenario

For inflation linked bonds, floating rate bonds (CCT) and corporate bonds it is assumed a downside price variation equal to 1.20 the Margin Interval in force.

5.3. Steepening and Flattening Scenarios

Two other hypothetical scenarios - implying non-parallel shift of the Italian yield curve and Eurozone yield curve - may be applied:

a) **Steepening:** +/- n *basis point* on the vertex "x" and +/- m *basis point* on the vertex "y",

b) **Flattening:** +/- n *basis point* on the vertex "x" and +/-m *basis point* on the vertex "y",

where x and y are two possible vertices of the curve, divided into 45 discrete vertices, while *n* and *m* are shocks defined time-to-time by Risk Management. In particular, the vertex x corresponds to a shorter maturity and y to a longer one.

For steepening scenario (Figure 3) the basis point increase on the first vertex x is lower (e.g. 0 basis points) compared to the one on the second (e.g. 100 basis points). Conversely, with regards to the flattening (Figure 4), the increase in terms of basis points is higher on the first expiry and lower on the second. The shift applied to the other vertices of the curve is determined by linear interpolation.

Figure 3: Steepening
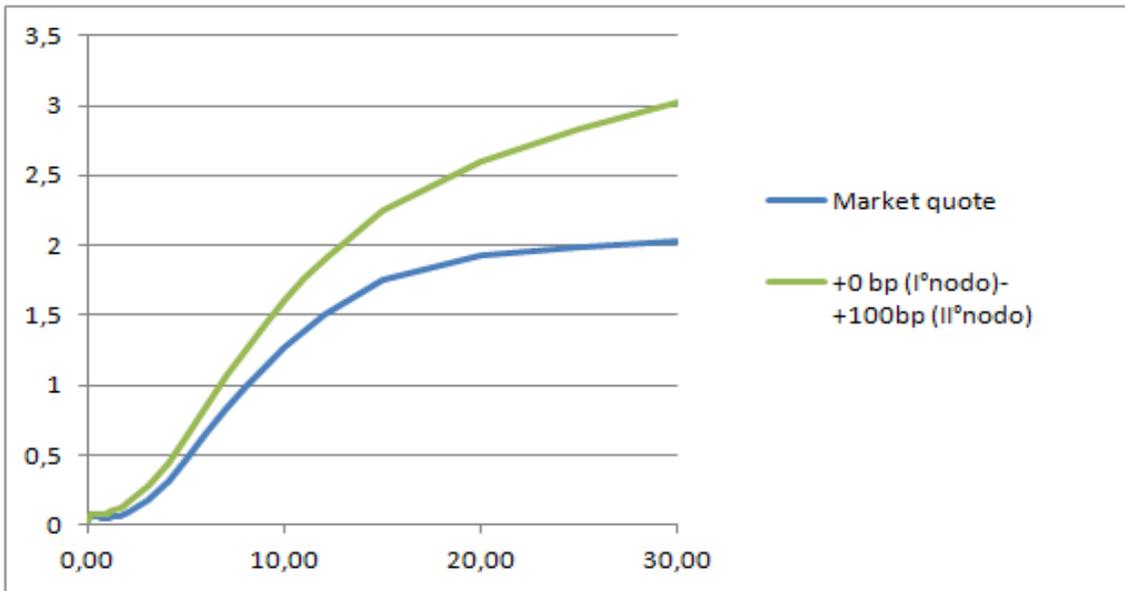
Figure 4: Flattening
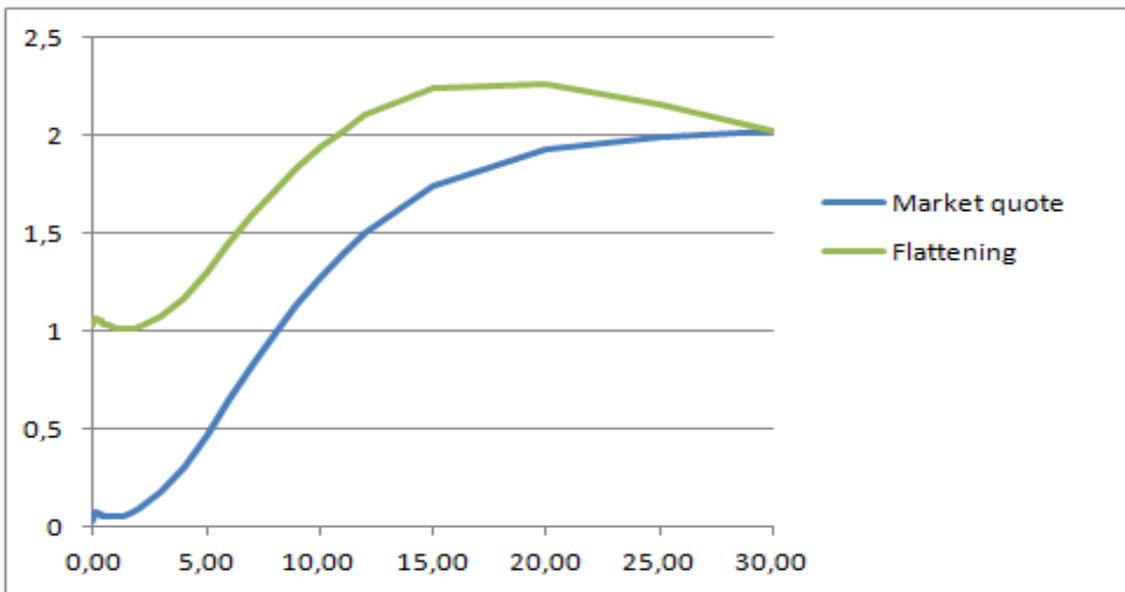
The following breakdown provides a summary of the hypotheses in the four Scenarios.

Hypothesis	Yield Increase	Yield Decrease
Fixed rate bonds (BTP), CTZ (Zero-coupon securities), Treasury bills (BOT)	Largest between the largest upside and downside, one-day, two-days, three-days, four-days and five-days yield variations.	Largest between the largest upside and downside, one-day, two-days, three-days, four-days and five-days yield variations.

	Yield Variations resulting of the linear interpolation of the largest variation for the previous and next vertices to the duration of the bond.	Yield Variations resulting of the linear interpolation of the largest variation for the previous and next vertices to the duration of the bond.
Inflation Indexed Bonds (BTPi and BTP Italia), Floating Rate Bonds (CCT), Corporate Bonds	1.20 the size of the Margin Interval	1.20 the size of the Margin Interval

Steepening	Flattening
+/- n basis point on the vertex "x" and +/- m basis point on the vertex "y"	+/- n basis point on the vertex "x" and +/- m basis point on the vertex "y"

6.0   Agricultural Commodities Derivatives Section Scenarios

For the Agricultural Commodities Derivatives Section simplified stress test scenarios are hypothesized, until enough statistically significant data will be available.

In particular, four Stress Test Scenarios are used: a Downside Price Variation Scenario and an Upside Price Variation Scenario, as hereby described.

6.1.   Downside Scenario

The hypothesis is that each position – ordinary and delivery – has a downside price variation equal to the worst of the following events:

a) 1.20 times the « Margin Interval in Force»;

b) the largest (both upside and downside) among one-day, two-days and three-days future price variation actually occurred over the available time series of *comparables*;

6.2.   Upside Scenario

The hypothesis is that each position – ordinary and delivery – has an upward price variation equal to the worst of the following events:

a) 1.20 times the « Margin Interval in Force»;

b) the largest (both upside and downside) one-day, two-days and three-days future price variation actually occurred over the available time series of *comparables*;

The following tables provide a summary of the hypotheses in the two Scenarios for the ordinary positions and for the delivery ones.

Ordinary and Delivery Positions		
Hypotesis	Downside	Upside
a)	1.20 the size of the Margin Interval	1.20 the size of the Margin Interval
b)	**largest** price variation (upside or downside) in the whole time horizon available	**largest** price variation (upside or downside) in the whole time horizon available

Appendix - Stress scenarios for collateral

The Non-Collateralized Exposure (NCE) is calculated under the assumption that Participants have deposited an amount of collateral - in cash or Securities – equals to or greater than the amount calculated by CC&G as Initial Margins.

The stress time to time applied to the collateral is different according to the section.

Step 1-A Calculation of stressed collateral value of securities for the Equity and Derivatives Section, Energy Derivatives Section and Agricultural Commodities Derivatives Section

For all Sections apart from Bond Section, the stressed countervalue of collateral posted in securities by each Clearing Member is always stressed according to the *Yield Increase Scenario* applied to Bonds.

The new countervalue of the collateral is then split on each section using the margins as allocation criterion. Therefore:

$$Collateral(\alpha)_{CMi} = Total\ Collateral_{Stressed} * \frac{Margins\ (\alpha)_{CMi}}{Total\ Margins_{CMi}}$$

where:

- α is the n-th section where the Clearing Member participates;
- Total Collateral$_{stressed}$ is the value of the collateral posted in securities, stressed according to the *Yield Increase Scenario*;
- Total Margins$_{CMi}$ is the total amount of margins calculated for the i-th Clearing Member.

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Step 1-B: Calculation of Stressed Collateral value of securities for the Bond Section
The stressed countervalue of the collateral used for the Bond Section is determined according to the same scenarios applied to Bond Section itself.

The total countervalue of the collateral For Bond Section is calculated consistently with the stress scenario elaborated on the sector itself (e.g. Yield increase, Yield decrease, steepening).

After scenarios have been applied, the collateral allocated to the Bond Section is determined as follows:

$$Collateral(Bond\ Section)_{CMi} = Total\ Collateral_{Stress\ scenario\ j} * \frac{Margins\ (Bond\ Section)_{CMi}}{Total\ Margins_{CMi}}$$

where:

- Total collateral$_{stress\ scenario\ j}$ is the value of the collateral after stress used by applying the same j-th scenarios applied for the Bond Section;

- *Margins (Bond Section)* is the total amount of Margins for the i-th Clearing Member on the bond section;

- *Total Margins$_{CMi}$* is the total of margins calculated for the i-th Clearing Member.

Step 2: Calculation of the cash collateral for each section
As for collateral posted in securities, also cash collateral is allotted among the different Sections according to the same criterion:

$$Cash\ Collateral(\alpha)_{CMi} = Total\ Cash * \frac{Margins\ (\alpha)_{CMi}}{Total\ Margins_{CMi}}$$

Step 3: Calculation of the total collateral for each Section
The stressed value of the total collateral (cash and securities) calculated for each Participant may result greater than the amount of margins.