Negative Interest Rates Environment in Front and Risk systems

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April 2017

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Acknowledgments:
this work has benefited of the contribution of many present and former colleagues, in particular the Internal Validation, Risk Methodologies and the Financial Engineering teams of Unicredit Group.

MAIN TOPICS

- ❏ Low and Negative Rates Environment: Overview
- ❏ Front Office Environment
- ❏ Risk Environment

- ▌ Describing evolution of the pricing and risk framework during the drop in Interest Rates of the EUR Area since 2013
- ▌ Case study examples in FO: Caps and Floors
- ▌ Impact on the computation of Risk Measures
- ▌ Regulatory Environment Interactions: Model Changes
- ▌ Extension to Commercial Banking Book positions

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FRONT OFFICE PRICING FRAMEWORK FOR INTEREST RATES

❑ Vanilla Products priced by Native FO system (Murex, Sophis, K+) Models
- Linear Products (IRS, CCS): multi-curve Discounted Cashflows
- Caps and Floors: caplet volatility stripped from Market Quotes and passed to native pricers after proper interpolation
- European Swaptions: volatility extracted from Market Data, then passed to native pricers after proper interpolation

❑ Exotic Derivatives evaluated by different approaches (Monte Carlo Simulations, trees, PDEs, numerical integration)
- Libor Market Models (possibly with Stochastic/Local Volatility)
- simpler Term Structure Models (e.g. Gaussian Models, with Stoch Vol)
- Swaptions-related products (Constant Maturity Swaps, CMS Spread Options) via replica approach (weighted integral of swaptions prices)

Front Office Pricing Framework for Interest Rates

- ❑ Traditional set up of vanilla pricers was based on Black formula, implying positive forward rates as input
- ❑ All Exotic Models inherit Market Data from the Vanillas

Risk Environment Pricing Framework for Interest Rates pre–2013

- ❑ Scenario Generation (Value–at–Risk and Counterparty Credit Risk Models): usually Models implying positive (forward) rates were chosen:
  - ▮ Introduction of Flooring Mechanism in Historically Based Models
  - ▮ Models with positive Interest Rates (CIR, BK) for Monte Carlo Models

New Environment in EUR Area (FO and Risk)

- ❑ Cope with negative discounting and forwarding rates
- ❑ Low Rate Environment: options with negative and zero strikes, embedded in Bonds and Derivatives, have non zero price.
- ❑ Negative Forwards to be plugged into Black Formula: flawed sensitivities.

FRONT OFFICE PRICING FRAMEWORK FOR INTEREST RATES

❑ Vanilla Options (Cap/Floors and Swaptions) priced via Black–Formula. Market Quotes are calibrated and then Black Volatility is interpolated

▐ Caps/Floors surfaces and Swaptions Cube are the input for the valuation of more exotic derivatives, i.e. they are used for the calibration of IR Models

▐ Caps/Floors and Swaptions are used as hedging instruments

RISK FRAMEWORK

❑ Risk Pricing framework should be aligned to the FO revaluation

❑ VaR scenarios: when rates are low, shocks may bring them into the negative region

▐ flooring to ensure positive forwards

▐ intrinsic valuation for vanillas if shocks to the market data imply negative forwarding curve and fallback solution for exotic derivatives

❑ CCR Scenarios: Models like Black Karasinski or CIR with positive Rates.

Changing Paradigm: Short Term IR approaching zero in the EUR Area (less than 50 bp). Although forward rates were still positive, the low Rate Environment brought in some novelties in the IR World

- Low Strike Floors prices rise. Black Volatility reached large values to accommodate for pricing.

- New strikes were introduced in Brokers' pages. 0 Strike Floors started being quoted

- Broker introduced Displaced Volatilities and Normal Volatility in addition to Black Vols.
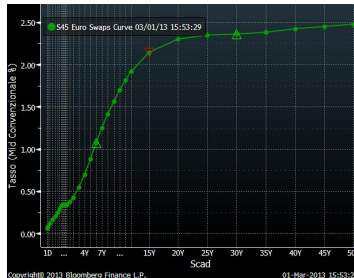
❑ Bonds (and relative Asset Swaps) embedding low and negative strike options had to be properly represented and priced.
  - ▮ Euribor + Spread coupon implied a floor @ –Spread
  - ▮ CMS linked Bonds implied a CMS floor @ 0 strike

Short term pillars of OIS Curve showed negative discount rates

- Negative Discount Curve affected all collateralized deals.

- No major issues in vanilla option valuation (only a few OIS Options)

- Models for Exotic Derivatives in multi curve framework: if the model implies positive rates, and simulates the discount curve, corrections are necessary.

RISK SIDE

❏ since mainly discount is impacted, Pricing on Risk scenarios shows no major issues

❏ if models chosen for Risk Scenario Generation imply positive Interest Rates, P&L and Exposure Distribution may be biased with respect to baseline Prices.

Short–medium term pillars of EUR forwarding Curves reached the negative region

❑ Need to change the pricing models for Vanillas and Exotic

❑ Most Straightforward solution: Introduction of a Displaced Dynamics (Shifted dynamics replacing the original dynamics).

- ▌ Caps/Floors
- ▌ Swaptions
- ▌ Constant Maturity Swaps related products via replica
- ▌ Term Structure Models (e.g. Displaced Libor Market Models)

❑ Improving the calibration of Market Quotes

❑ proper deal revaluation

❑ P& L jumps after the introduction of new pricers

❑ Relevant impacts on Sensitivities

❑ Re–Hedge books

❑ New issue: how to determine displacement. Judgemental, Calibrated or implied Parameter?

Short–medium term pillars of EUR forwarding Curves reached the negative region

Impacts on Risk Models

❏ Modify Pricing Framework in order to be consistent with the FO
- ▮ VaR Model: Risk Pricing must be as coherent as possible with FO pricing, in order to avoid Economic P&L exceptions driven by different revaluation models.
- ▮ CCR Measure: Future Mark–to–Market and Exposures have to be computed with Models as close as possible with FO, in order to avoid incurring in overdrafts of Credit Lines driven by different pricing models.

❏ Review and update Risk Simulation Models
- ▮ Retrieve Market Data (e.g. Displaced Volatility) to calibrate Risk Models
- ▮ Amend the stochastic processes to allow negative rates
- ▮ Regulatory Interactions for Model Change

Short–medium term pillars of EUR forwarding Curves reached the negative region

IMPACT ON RISK PROCESSES

❑ Set Independent Price Verification for possible new Market Data (Displacement?)

❑ Fair Value Adjustments and Additional Valuation Adjustments

  ▮ Typically Vanilla Derivatives, whose models are mainly encoding market information, require only Market Quotes driven adjustments (Close out Costs, Bid–Ask, MPU...), while Exotic products require Model Risk in addition

  ▮ Before the switch to the new model, differences in revaluation can be booked as Model Risk: impacts also on vanilla products

❑ Limits & Risk Appetite: provided that Greeks are changed, also Limit usage is different. The setting of new limits, coherent with the Bank's target, enter into the Risk Appetite Framework

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CAPS AND FLOORS

❑ Zero and Negative Strike Floors

▮ In the previous Black framework, a lognormal dynamics for the Forward Rates was assumed. As such, Zero and Negative Strike Floors are priced at intrinsic value. No effect of volatility (zero vega), also in case of positive forwards (issue already in 2013)

❑ Caps and Floors in the presence of negative forward rates: in Black's formula, the price is the intrinsic value of the caplet (also at large strikes).

▮ Zero Black Vega for the caplets with negative forward rates

❑ Zero Floor CMS: in a lognormal framework (with smile) such derivatives are not given a positive value, while they have been quoted since late 2014.

❑ Libor Market Model: assumes lognormal dynamics (w/o stoch vol), which is inappropriate for the first forward rates (negative initial value)

❑ Low Strike Swaptions: to reproduce market prices, also in case of positive forward Swap Rates, Black Volatility reaches high values (above 100%) which makes interpolation (for instance SABR calibration) problematic

In the Black Framework, Market Quotes cannot be calibrated properly any more. Below we present Price differences (Market Price vs Calibrated Model Price), in basis points, for low strike Floors with different models. Both models were calibrated to the existing quotes, but Black approach fails to reproduce the lowest strikes (2015 Market Data).

	0.000%	0.125%	0.250%	0.375%	0.500%	1.000%
1.0						
1.5						
2.5	-17					
3.5	-16	-10				
4.5	-26	-17				
5.5	-40	-27	-2			
6.5	-58	-41	-10			
7.5	-75	-54	-16	-1		
8.5	-93	-68	-23	-1	1	
9.5	-112	-84	-33	-5	0	
10.5	-134	-103	-45	-11	1	
11.5						
14.5						
19.5						
24.5						
29.5						-88

Black Model

	0.000%	0.125%	0.250%	0.375%	0.500%	1.000%
1.0						
1.5						
2.5	-9					
3.5	0	-1				
4.5	0	-1				
5.5	1	-1	1			
6.5	1	-1	0			
7.5	0	-1	1	-1		
8.5	0	-1	1	-2	1	
9.5	1	-1	0	-2	1	
10.5	1	-1	1	-1	1	
11.5						
14.5						
19.5						
24.5						
29.5						8

Displaced Black Model

For Zero Strike Caplets and Floorlets, Black price corresponds to intrinsic value, while Displaced Black price factors in properly volatility effects. In the first case, zero vega position is computed with underestimation of risks and incorrect hedging

Floorlets @ Strike 0

Caplets @ Strike 0

For positive Strikes, Black Formula yields intrinsic value if Forwards are negative. Test case:

- Set a Forwarding Curve with negative forwards up to 5 years
- Set a Flat Black Vol of 100%
- Recover a Displaced Flat Vol that yields the same Cap price
- Plot Caplets and Floorlets to see the profile differences which correspond to the same Market Price (ideally a Market Quote)

Caplets @ Strike 1%

For positive Strikes, Black Formula yields intrinsic value if Forwards are negative. Test case:

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Caplets @ Strike 1%

Given the different values attributed to each caplet (although Cap price is the same) and considering that the shortest expiry Caplets are priced at intrinsic value by Black Formula, the Vega exposure is very different. In particular:

- for Black Model, Vega is nonzero only at expiries larger than 5y.
- Vega Sensitivity is typically one order of magnitude larger for the Displaced Black Model.
- The Risk profile is very different, and hedge ratios change dramatically.

Vega Caplets @ Strike 1%
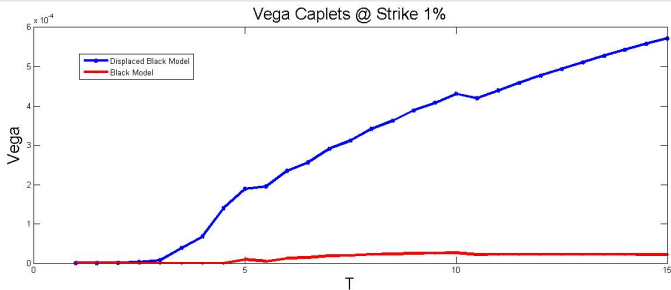
The same argument above presented for Vega holds for Delta. Here we plot the effect of a parallel shock of the Interest Rate Curve. The Model behavior is totally different, also if the PV of the deals is the same by construction. From a Risk perspective, Displaced Black is much more sensitive to the short term pillars of the Curve, that are the most volatile.
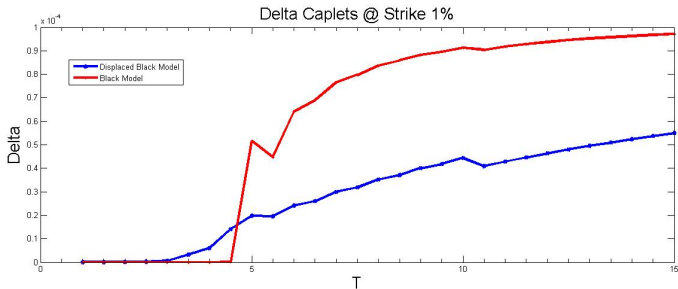
In order to cope with the new pricing paradigm, the Models used to revaluate the exotic portion of the book have to be refactored/enhanced. In parallel with the vanilla book, this may lead to non negligible P & L jumps:

❏ Displacement embedded in the dynamics, where necessary
   ▮ For instance, Hull & White based models do not need adjustments, since they allow negative rates

❏ New Calibration Algorithms & Strategies
   ▮ Approximated analytical formulas usually perform better with lower volatilities, as in the case of displacement.
   ▮ in principle, displacement may be calibrated to the vanilla quotes

❏ Hedging
   ▮ Sensitivity to the displacement
   ▮ All sensitivities modified, both for vanilla and exotics: hedge books to be updated with the new hedge ratios.

NEW PRICING FRAMEWORK – ISSUES TO BE TACKLED

❑ Management of the displacement
- ▌ Calibration on Market Quotes
- ▌ Judgemental Parameter
- ▌ Implied from Market Data (e.g. Swaptions Quotes from ICAP)

All the alternatives have pros and cons. In particular, calibration may be a strategy for Exotic Models, provided that one does not incur in over parameterization. Setting it as a Judgemental might have consequences from the accounting (Level 3) point of view

❑ Delta and Vega Sensitivity
- ▌ Vega and Delta depends on the displacement level
- ▌ Aggregated Vega could not be meaningful: granular hedge is necessary

❑ Extension of scope of Model Risk: vanilla products have been considered for a long time *Model Risk free*. The in-transit situation during the model change has to managed with proper reserves mechanism

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PROPER MANAGEMENT OF RISKS AND RELIABLE RISK WEIGHTED ASSETS

Pricing for Risk Measure computation has to be aligned to Front Office. VaR Backtesting procedures may show non–genuine overdrafts for the economic P&L if relevant differences in the revaluation are present. On the CCR side, future exposures have to be computed coherently with current exposures to have an effective Credit Line Monitoring. So Risk Models have to be enhanced:

❑ Pricing Models, introducing the same pricers of the FO (displacement)

❑ Market Data Management: new market data has to be included in the IPV

❑ Risk Scenario Generation: Floor Removal or extension of simulation models into the negative area

❑ Sensitivity: Sensy in the new framework may be different with respect to Black's world. Limit Review in Risk Processes

❑ Regulatory Interactions: if the model is approved by Supervisory Authorities, each change in RWA computation has to follow Regulatory Technical Standards (for VaR) or ECB Guidelines (for CCR). If the model change is deemed material, ECB Approval has to be granted before going live.

RISK ENVIRONMENT
MARKET DATA

RETRIEVING AND VERIFYING MARKET DATA

New Market Data (including displacement) has to be retrieved and verified in Independent Price Verification process and for VaR computation

MARKET QUOTES

Swaptions Black Volatilities compared with Displaced Black Volatilities

RETRIEVING AND VERIFYING MARKET DATA

New Market Data (including displacement) has to be retrieved and verified in Independent Price Verification process and for VaR computation:

- Including Displacement in the dataset

- choose the drivers to build risk scenarios: volatility only or also displacement?

- In case displacement changes over time, volatility shocks have to be computed coherently to avoid under/overestimation of Risk

In case of Linear Derivatives, like Interest Rate Swaps, flooring in VaR scenarios alters the profit and Loss Distribution in a significant way.

- Test case: IR Curves negative up to 5Y Pillars
- Comparison of Mark–to–Market in risk scenarios generated assuming positive interest rates and without any flooring.
- Linear Books generally show biased P&L distribution, with under/overestimation of VaR

Frequency Distribution for different Risk Scenarios assumptions
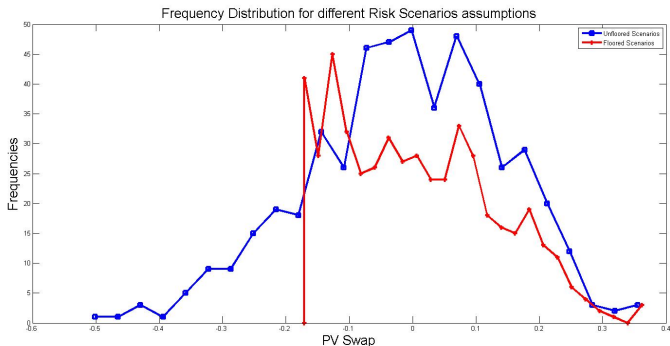
For Non–Linear Derivatives (e.g. Caps), in the new Risk and Pricing approach several effects mix up

- Flooring Effects on VaR scenarios as for Linear Derivatives
- Different Pricing Models changes the revaluation on risk scenarios
- Volatility Risk scenarios are different, for instance if displacement is factored in.
- Due to the different Sensitivity, the responsiveness of the instruments to risk scenarios may be very different
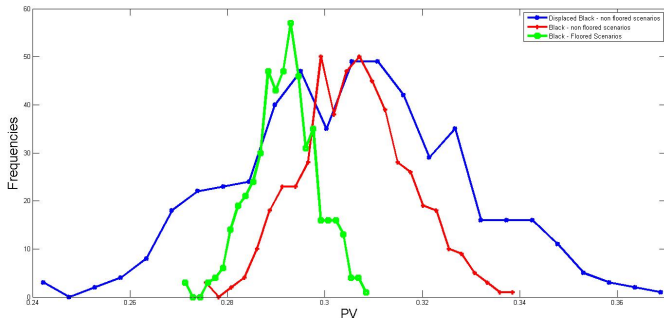
In the CCR the same effects as VaR are found, which may affect Exposure estimation.

- Flooring Effects as for Linear Derivatives
- Different Pricing Models change the revaluation on risk scenarios
- Volatility Risk scenarios are different, for instance if displacement is factored in.
- Effects on Expected Positive Exposure depends on several factors like deal expiry and moneyness
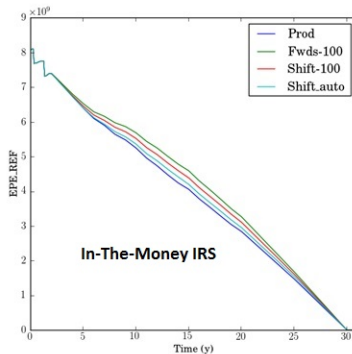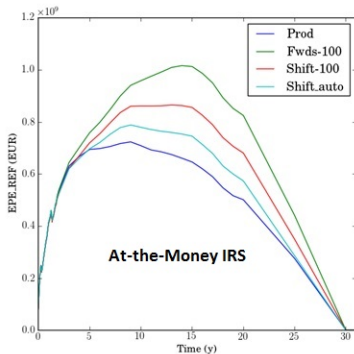
ENHANCEMENT OF RISK MODELS TO RESTORE PROPER RISK MANAGEMENT

If the Risk Models are used for Regulatory purposes, *i.e.* Computation of Risk Weighted Asset, they are subject to Approval from the Supervisors. Changing such models implies following Model Change Rules, potentially asking for approval to the Regulators. For Market Risk Models, EBA Regulatory Technical Standards describe:

❑ A classification of changes of the Risk Environment

❑ How to assess the Materiality of the Model Change

❑ The documentation to be provided to ECB and the path to activate the new model.

The Materiality Assessment is an effort consuming activity, since it may need an extended testing phase

❑ a Model change is deemed *not material* if in the first day of testing the difference in VaR (and RWA) is below 1%, or in a 15 business days parallel run the impact is below 10%. In this case, an ex-ante or ex-post notification to Supervisors is enough to deploy in production the new model

❑ in all the other cases, a Model change request has to be filed asking for Regulatory Approval. This may take a few months including on-sites inspection.

Apart from traded instruments (Bonds and Derivatives), negative interest rates affects also Commercial Banking Book positions, namely

LOANS AND MORTGAGES

Installments are composed of Principal Payment and Interest Payment. In case of Interest amount linked to some Market Rate (e.g Euribor 3M + Spread), the loan could have optionality embedded, depending of contractual features:

❏ Interest amount floored at 0: this corresponds to a floor @ –Spread

❏ the underlying Market rate could be subject to flooring before computing the interest amount: floor @ 0

❏ no flooring considered

SIGHT ITEMS AND TERM DEPOSITS

Deposits and assets with not defined contractual maturity and Term deposits can be linked to Market Rates as well.

❏ Sight Deposits typically are associated to 0 floors, while sight assets to floors @ –Spread

Although from a financial point of view Commercial Banking Book optionality can be priced (and risk managed) as in the Trading Book, behavioral models enter the game

LOANS AND MORTGAGES

Loans and Mortgages have contractually defined amortizing profiles. Anyway, for the Interest Rate Risk of the Banking Book (IRRBB) and Liquidity management, Banks models prepayment of loans modifying the contractual profile. As a result, the amortization is modified to embed the probability of prepayment.

SIGHT ITEMS AND TERM DEPOSITS

Sight items (e.g. Deposits) contractually can be mapped to overnight. Anyway, Deposits show a certain degree of stickiness well beyond one day. Historical data are used to devise the behavioral models used to estimate the profile of sight items, associating

- ❏ Reference Rate (fixed or linked to Market Rates)
- ❏ core versus non core component
- ❏ amortizing profile for the core component

The interplay of Behavioral Models and optionality embedded in Commercial Banking Book positions is not always straightforward

- ❑ Amortizing profile of the embedded options is determined by the choices in behavioral modelling
- ❑ in some cases, behavioral models are estimated also using market rates as regressors

RISK MANAGEMENT

As a result, Negative Interest Rates in the Commercial Banking Book significantly modify IRRBB methodologies and monitoring processes, given the huge positions of loans and deposits:

- ❑ Embedded optionality, not considered before, affects Sensitivities and VaR of Banking Book
- ❑ Commercial Banking book shows large vega positions, although some natural hedging among loans and deposits is present
- ❑ impact of behavioral choices on Risk Metrics is even more important, and cannot be hedged

The EUR Area Low and Negative Rate Environment had as consequence a deep revision of the Interest Rates Derivatives Pricing and Risk Framework

FRONT OFFICE – NEW PRICERS AND MARKET DATA

- ❑ New Pricing Paradigm on the FO side, abandoning Black's pricing approach. Enhance the pricing for vanillas and exotics
- ❑ Revision of hedges for IR Books as consequence of changes in the pricing approach and of the new market data available (displacement)

RISK MANAGEMENT – REVISION OF THE RISK MODELS

- ❑ Enhancements of Revaluation Framework, to ensure coherence with FO
- ❑ Modification to the Scenario Generation Framework
- ❑ Introduction of new Market Data
- ❑ New Sensitivity and need to avoid vega aggregation
- ❑ Revision of Limit setting, including the Risk Appetite Framework
- ❑ Model Change needed and interaction with Regulators
- ❑ Interest Rate Risk of the Banking book Methodologies to be reviewed