Theoretical and Practical Challenges Connected with Negative Interest Rates

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The Motivation Behind Negative Rates

- The financial crisis, which started 2007, exposed a lack of trust among counterparties.
- Since then incorporation of the probability of default in pricing models became standard.
- The lack of trust in the financial system reduced trading activities and kept the money in the pockets.
- To recover trust central banks decided to intervene and stimulate the monetary supply and demand.
- Lowering the interest rates was expected to encourage investors to borrow money at a low rate and invest into the economy, which would push the economy to grow.
- Since 2008 interest rates have gradually been lowered.

The Motivation Behind Negative Rates

- June 5th 2014, the rates set by ECB were negative for the first time: minus 10 basis points.
- Using negative rates is unconventional to “inspire” investors but it is not unprecedented (Switzerland, Sweden and Denmark also report negative rates).

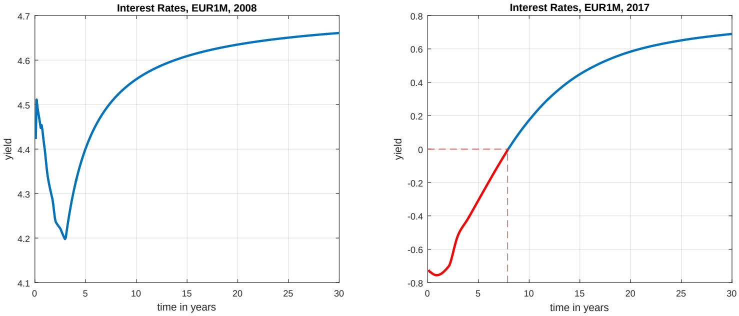

Figure: Both figures present the yield obtained from EUR 1M curve, left: 2008 and right: 2017.

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Modeling Challenges

- For decades the pricing models which generated negative rates were considered unrealistic and simplistic.
- The Hull-White model, which "suffered" from negative rates, has been widely used in the industry.

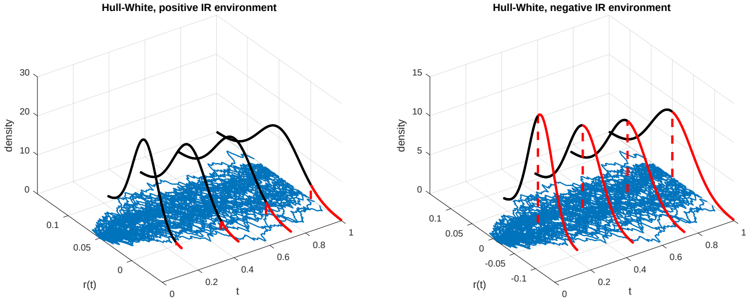

Figure: Both figures present the Monte Carlo Paths for the Hull-White model in a positive and negative interest rate environment.

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Modeling Challenges

- Once the rates/forward become negative, it is no longer possible to price interest rate derivatives by the famous Black formula:

$$
\begin{aligned}
black(t_0, T, K) &= P(t_0, T)\left[F \times N(d_1) - K \times N(d_2)\right], \\
d_1 &= \frac{\boxed{\log F/K} + \frac{1}{2}\sigma^2 T}{\sigma\sqrt{T}}, \\
d_2 &= d_1 - \sigma_1\sqrt{T}.
\end{aligned}
$$

- Immediate market response to negative rates was the incorporation of a "shift":

$$\hat{F} = F + \theta.$$

- The shift parameter θ is quoted in the market (for every expiry and tenor).
- Shifts change over time, i.e. they increase.

Modeling of Volatility

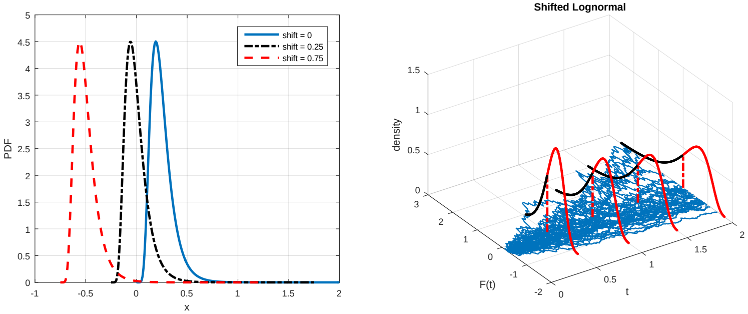

Figure: Shifted lognormal distribution used for pricing in negative interest rate environment.

Modeling of Volatility

- Each non-linear product relies on volatilities that are extracted from market quotes.
- Because of limited liquidity the volatilities are parameterized.
- Unfortunately, the parameterizations are often not arbitrage-free, especially not in the low/negative interest rate environment Grzelak et al. [2014]; Grzelak and Oosterlee [2016].

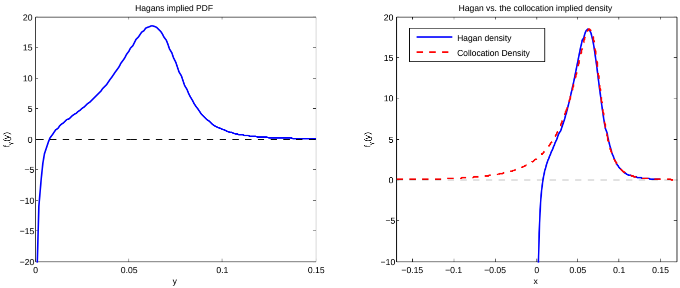

Figure: Probability density, with deterioration near zero; right: application of the collocation method

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Modeling Challenges and Client Relations

- Often, floating rate bonds are issued with coupons paid with a spread above the index.
- Shall the bond issuer request the payments from bond holders in the case the coupon payment is negative: $cpn_i = L(T_i, T_i, T_{i+1}) + spread < 0$?
- To maintain a good client relation often coupons are calculated by $cpn_i = \max(L(T_i, T_i, T_{i+1}) + spread, 0)$. This however requires incorporation of **volatilities**.

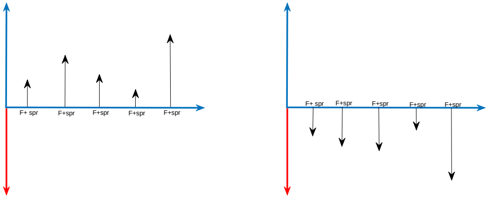

Figure: Left: standard coupons in positive rates environment, Right: degenerated flow where bond holders needs to pay coupons.

References

Grzelak, L. and Oosterlee, C. (2016). From arbitrage to arbitrage-free densities. *Journal of Computational Finance*.

Grzelak, L., Witteveen, J., Suarez, M., and Oosterlee, C. (2014). The stochastic collocation Monte Carlo sampler: Highly efficient sampling from "expensive" distributions. *Available at SSRN: http://ssrn.com/abstract=2529691*.

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