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Implications of implicit credit spread volatilities on interest rate modelling

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ABSTRACT

We test seven term structure models in the Heath, Jarrow, and Morton (1992) class in order to find the best representation of the Libor rate in interest rate markets after the credit crunch of 2007. The Libor rate is considered as a risky rate, subject to the credit risk of a generic counterparty whose credit quality is refreshed at each fixing date. We study the volatilities of the credit spreads implicitly obtained from Libor time series. In order to understand how assumed volatility functions affect interest rate curve modelling and asset pricing, we develop a model to estimate basis swap prices through the Monte Carlo simulations. We compare obtained results and individuate systematic relations existing between the basis spread forecast error and both the accuracy in volatility modelling and the accuracy of the Monte Carlo estimates. We analyse and document these relations by defining appropriate pricing error measures.

1. Introduction

A number of stylized facts about anomalies arisen in the interest rate market after the credit crunch of summer 2007 have been uncovered in the literature. Some examples are the appearance of basis spreads between interest rates with different tenors, the loss of the possibility of pricing swaps by using market spot rates, and the fact that the interest rate curve underlying of interest rate derivatives does not coincide with the discounting interest rate curve anymore. Among many articles that deal with the credit crisis and its consequences and propagation we recall Paltalidis, Gounopoulos, Kizys, and Koutelidakis (2015), Terradez, Kizys, Juan, Debon, and Sawik (2015) and Kizys, Paltalidis, and Vergos (2016). However, the most relevant consequence of the credit crisis is that a spread has opened up between the Libor rates and the risk-free Eonia OIS rates, Overnight Indexed Swaps rates. This event has led to a new mathematical modelling of the Libor rate as a risky interest rate. The credit risk of the Libor rate can be measured by a credit spread that is not referred to a specific counterparty, but to a generic one whose credit quality is refreshed at each fixing date. The fixings are trimmed averages of contributions from a panel of the most relevant banks in the market with the highest credit quality.

In the literature many authors propose new approaches for modelling the Libor rate, such as Mercurio (2009), Ametrano and Bianchetti (2009), Henrard (2010), Pallavicini and Tarenghi (2010), Morini (2011), Crépey, Grbac, and Nguyen (2012), Bianchetti and Morini (2013), Pallavicini and Brigo (2013), Crépey, Grbac, Ngor, and Skovmand (2017), Grbac and Wolfgang (2015), and Fanelli (2016). However, in the field of operational research several researchers attempt to provide an appropriate representation of interest rate dynamics by modelling its volatility in order to obtain an accurate price of financial assets. Bali (2007a) estimates the interest rate volatility through an extreme value approach. He shows that during the extreme movements of the U.S. Treasury market the volatility of interest rate changes is underestimated by the standard approach that uses the thin-tailed normal distribution. The author analyses the pricing implications for interest-rate options. Bali (2007b) models the dynamics of interest rate volatility with skewed fat-tailed distributions through a discrete time GARCH model. He finds that the GARCH model performs better than a CEV model in forecasting the future volatility of interest rates. Jacobs and Li (2008) propose a two-factor model for credit spreads. The first factor is the level of credit spreads, the second factor is the volatility of credit spreads. They show that a stochastic volatility model performs better than a model in which the volatility is not a state variable. Falini (2010) compares different multi-factor HJM models with humped volatility structures and develops empirical applications. He finds the humped volatility specification to greatly improve the model estimation and to provide sufficiently accurate cap prices. Clark and Baccar (2015) suggest that credit spread changes are mainly explained by the interest rate and interest rate volatility, the slope of the yield curve, stock market returns and volatility, the state of liquidity in the corporate bond

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market and the foreign exchange rate. They find that asymmetric GARCH models and Student-t distributions are more suitable than conventional GARCH in modelling credit spread volatility. Moreno and Platania (2015) propose a cyclical square-root continuous-time model for the term structure of interest rates, where interest rate volatility depends on the interest rate level and is driven by harmonic oscillators. Their model outperforms the Cox, Ingersoll, and Ross (1985) model.

Although all the above papers give a contribution to the operational research literature in terms of interest rate volatility modelling, to the best of our knowledge and to date, there is no published paper that focuses on a comparison of volatility models for credit spreads and their impact on interest rate derivative pricing. In this paper, we aim at filling this gap in the literature.

We investigate the characteristics of the credit spread volatility and we test seven specific term structure models for credit spreads in the Heath, Jarrow and Morton (1992) (HJM, henceforth) class, which use seven different volatility functions as inputs. From market data we obtain the daily term structure of forward credit spreads, defined through the implied default intensity of the contributing banks of the Libor corresponding to a chosen tenor. Furthermore, we evaluate the implicit credit spread volatilities. For each model, we use these data to estimate the volatility function parameters. In order to assess the accuracy of models in representing the behaviour of the credit spread, we test their ability to predict the price of an interest rate derivative, the basis swap. We document systematic discrepancies between the various models and market prices, as a function of the accuracy of the chosen volatility model and the accuracy of the Monte Carlo estimates. We identify and quantify the effect of the implicit volatility modelling on the accuracy of the basis spread pricing model by defining proper pricing error measures. We find that the choice of an appropriate volatility function allows us to increase the accuracy of estimates regardless of the simulation precision. Based on our results, we conclude that more importance should be given to the choice of the most accurate volatility model because in this way computational efforts – in terms of number of simulations in the Monte Carlo approach and time-consuming level – could be reduced, even maintaining a high level of precision in pricee HJM model is automaticestimates.

The HJM approach offers several advantages in modelling term structures in the arbitrage-free environment (see Bielecki & Rutkowski, 2000; Brigo & Mercurio, 2006; Heath, Jarrow & Morton, 1992). The HJM model is automatically calibrated to the initial yield curve. As a results, claim prices are completely determined by a description of the volatility structure of interest rate changes. In particular, the drift term is a function of the volatility, so that estimates of expected rate changes are not needed. In addition, it is possible to have different HJM models choosing different volatility functions, also path-dependent, giving the possibility to make the model consistent with the real market situation. We exploit these features of the HJM approach to investigate the implications of volatility function modelling on interest rate derivatives, through the definition of seven different volatility functions.

Much academic research has dealt with forward rate volatility specifications which give rise to HJM models, often path-dependent and multi dimensional. Among the most relevant papers we recall Amin and Morton (1994), Trolle and Schwartz (2009), Chiarella, Colwell and Kwon (2004), and Moreni and Pallavicini (2014). Amin and Morton (1994) are the pioneers in testing the HJM model according to different volatility functions. They study the time series of implied interest rate volatilities from the HJM models and price options in order to investigate the accuracy of the proposed models. Trolle and Schwartz (2009) develop a tractable and flexible multifactor model of interest rate term structure. Among features of the model they consider unspanned stochastic volatility factors and correlation between innovations to forward rates and their volatilities. The authors show the model has a very good fit to bonds and interest rate derivatives. Colwell and Kwon (2004) derive classes of interest rate models resembling the traditional models from the HJM framework, with the ultimate goal being the development of a unifying framework, or technique, capable of generating other models in a systematic manner. Moreni and Pallavicini (2014) propose a parsimonious model based on observed rates that deduces yield-curve dynamics from a single family of Markov processes. They calibrate the model with two driving factors and deterministic volatility to at-the-money swaption prices to size the effect of the new degree of freedom introduced to model different tenors.

In a great deal of literature, the HJM model has also been extended in order to model defaultable interest rate and price credit risk derivatives. We review some articles. Duffie and Singleton (1999) provide a discrete-time reduced form model in order to evaluate risky debt and credit derivatives in an arbitrage-free environment. They add a forward spread process to the forward risk-free rate process and use the HJM approach to obtain the arbitrage-free drift restriction. Collin-Dufresne, Goldstein, and Hugonnier (2004) demonstrate a pricing formula for defaultable securities, when the no-jump condition is violated. They introduce a new probability measure under which computing the expectation of claim cash flows. Henrard (2010) and Pallavicini and Tarenghi (2010) propose two different frameworks to construct yield curves consistent with a multi-curve situation and derive the price of interest rate derivatives. Chiarella, Fanelli and Musti (2011) develop a simulation approach for defaultable yield curves. The default event is modelled using the Cox process where the stochastic intensity represents the credit spread. The forward credit spread volatility function is affected by the entire credit spread term structure. They provide the defaultable bond and credit default swap option price in a probability setting equipped with a subfiltration structure. Crépey, Grbac, and Nguyen (2012) apply a defaultable HJM approach to model the term structure of multiple interest rate curves. They choose a class of non-negative multidimensional Lévy processes as driving processes combined with deterministic volatility structures, in order to obtain a flexible and efficient interest rate derivative pricing model. Eberlein and Grbac (2013) model credit risk within the LMM. They propose a rating Lévy Libor model that is arbitrage-free for defaultable forward Libor rates related to risky bonds with credit ratings. They use time-inhomogeneous Lévy processes as driving processes. Recently, Pallavicini and Brigo (2013) model multiple LIBOR and OIS based interest rate curves consistently, based only on market observables and by consistently including credit, collateral and funding effects. They develop a framework for pricing collateralised interest-rate derivatives. Crépey, Grbac, Ngor, and Skovmand (2017) develop a parsimonious Markovian multiple-curve model for evaluating interest rate derivatives in the post-crisis setup and they use BSDE-based numerical computations for obtaining counterparty risk and funding adjustments. Cuchiero, Fontana, and Gnoatto (2016) propose a general semimartingale framework for modeling multiple yield curves which have emerged after the last financial crisis. They use a HJM approach to model the term structure of multiplicative spreads between FRA rates and simply compounded OIS risk-free forward rates under a risk-neutral measure. They show that the proposed framework allows them to unify and extend several recent approaches to multiple yield curve modeling. Fanelli (2016) uses a defaultable HJM methodology to model the term structure of the credit spread, defined implicitly in the Libor. A forward credit spread volatility function depending on the entire credit spread term structure is assumed and a model for basis swaps is proposed.