ZERO-COUPON YIELD CURVE FOR NIGERIAN BOND MARKET

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ABSTRACT

The Nigerian bond market has developed to become one of the most liquid in Africa. However, to the best of our knowledge, the Nigerian bond market does not currently have zero-coupon yield curve; what is available is the yield-to-maturity yield curve. This paper seeks to model zero-coupon yield curve for the Nigerian secondary bond market, using piecewise cubic hermite interpolation. It also compares the existing yield curve with the zero-coupon yield curve to analyze the possible effects of relying on only the existing yield curve for financial market decisions. Data is obtained from the FMDQ OTC. The results show that the yield-to-maturity curve used by the Nigerian bond market generally appears flatter and more linear, relative to the modeled zero-coupon yield curve. We believe that adopting the zero-coupon yield curve in addition to the yield-to-maturity curve would add more reliability and accuracy for pricing decisions and monetary policy functions.

KEYWORDS

Nigerian bond market, zero-coupon yield curve, yield-to-maturity curve, piecewise cubic hermite interpolation, linear interpolation.

1. INTRODUCTION

The Nigerian bond market has been in existence since 1946 when the first government bonds – the development stocks – were issued. Based on a study, the Nigerian bond market is regarded as the second most liquid in sub-Sahara Africa – second to South Africa [1]. Particularly known for providing the most liquid platform for debt securities trading in Nigeria is the FMDQ OTC [2]. Many countries in Africa now regard the Nigerian bond market as a model from which to learn; and based on which to develop their respective domestic bond markets. For instance, in August 2015, a delegation of Kenyan financial market authorities visited the FMDQ OTC (FMDQ) to study the Nigerian OTC market and the E-Bond Trading System. In early 2017, a delegation from the Ghanaian financial market also went on a study tour to study FMDQ's businesses and operations, in order to upgrade their Ghanaian market operations" [3-5].

One important requirement for the development of every bond market is the sovereign benchmark yield curve. The government benchmark yield curve provides a yardstick for pricing various instruments, including corporate bonds [6]. According to IOSCO (2011), more than half of emerging markets do not have an efficient government benchmark yield curve to price corporate bond issues in the primary and secondary markets. The Nigerian bond market is one of the very few African bond markets which have benchmark yield curve [10]. To the best of our knowledge, even though the Nigeria bond market has a yield curve; it is a yield-to-maturity yield curve; but not zero-coupon yield curve, as recommended by Bank for International Settlements [7]. According to Bank for International Settlements (BIS), central banks (and bond markets) are expected to estimate and submit zero-coupon yields and also provide the method of estimation. Considering the fact that the Nigerian bond market is a model from which many other African bond markets are learning, we expect that it would have a zero-coupon yield curve.

The Nigerian yield curve is constructed by plotting the yields to maturity of bonds against their remaining terms to maturity [8]. Needless to say,

even though the yield-to-maturity curve is the most commonly observed yield curve on many bond markets and trading platforms, it has an obvious limitation [9].

"The main weakness of the yield to maturity yield curve stems from the un-real world nature of the assumptions behind the yield calculation. This includes the assumption of a constant rate for coupons during the bond's life at the redemption yield level. Since market rates will fluctuate over time, it will not be possible to achieve this (a feature known as reinvestment risk)."

Another issue we identify about the present Nigerian yield curve is the interpolation method being used. The simple (linear) interpolation method is used by the FMDQ to construct the Nigerian yield curve [10]. The linear interpolation is not continuously differentiable; and therefore, has the tendency of making the yield curve have kinks at data points. Consequently, a researcher sought to model the Nigeria's yield curve, using piecewise cubic spline interpolation [11]. However, the yields used were the primary market auction yields-to-maturity. The work didn't use secondary market zero-coupon yields. We therefore think that there is the need to have a secondary market zero-coupon yield curve; fitted with a method which is continuously differentiable. The purpose of this paper is to model the Nigerian secondary bond market zero-coupon yield curve with a method which is continuously differentiable.

2. METHODOLOGY

We adopt four steps in the yield curve modeling: (1) obtaining the daily bond data from FMDQ OTC website; (2) filtration of the bond data; (3) extraction of the yields and (4) interpolation and curve fitting.

2.1 Obtaining and filtration of data

Even though all federal government debt securities are listed on the Nigerian Stock Exchange, almost all active bond trading activities in

Nigeria take place on Over-The-Counter (OTC) platforms [12]. In 2016 for instance, the total value of secondary market trades in Nigeria amounted to 13,812.65 billion naira (45,287.38 million dollars). Out of this, the value of trade that occurred in the OTC market amounted to 13,811.85 billion naira (45,284.75 million dollars); that constituted more than 99.99% of the total secondary market trade. Since most active secondary market trades occur on the FMDQ OTC platform, we base our work on data from FMDQ. We obtain daily bond data from the website of FMDQ (www.fmdqotc.com). The data include government bond prices, coupon rates and maturity dates. The government bonds have maturities spanning from 91 days (3 months) to 20 years. The data is filtered to, as much as possible, exclude any erroneously recorded data item. We also ensure that we use on-the-run bonds for the work

2.2 Extraction of the yields

For the purpose of computing the yields, we use *Actual/365* as day-count convention and 2 days as trade settlement periods; per the trade guidelines of the Securities and Exchange Commission and Central Bank of Nigeria. To obtain the yields, we use the expression:

$$P(t, t_m) = \sum_{i=1}^m \frac{C * F}{(1 + R(t, t_i))^{t_i - t}} + \frac{F}{(1 + R(t, t_m))^{t_m - t}} \quad (1)$$

$P(t, t_m)$ = price of the coupon bond at time t , maturing at time m
 $R(t, t_i)$ = zero-coupon yield corresponding to $t_i - t$ time period, $i = 1, 2, 3 \dots m$
 F = face (or par) value of the bond
 C = coupon rate of the bond

$$P(t, t_m) = \sum_{i=1}^m C * F * \delta(t, t_i) + F * \delta(t, t_m) \quad (2)$$

$$\delta(t, t_i) = (1 + R(t, t_i))^{-(t_i - t)} \quad (3)$$

2.3 Curve fitting and interpolation of yields

As said earlier, linear interpolation methods are not differentiable; so they could produce yield curves which might not be smooth enough, compared to differentiable methods. However, we also don't recommend the use of the piecewise cubic spline interpolation because it has the tendency of producing excessively smooth and oscillatory curves that might overshoot at segments of the curve; since the cubic spline is continuously differentiable twice. To avoid these two extreme behaviors – lack of smoothness of the linear interpolation and excessive smoothness of the cubic spline interpolation – we adopt piecewise cubic hermite interpolation which is continuously differentiable once and is shape-preserving [13,14].

Assuming we have yield data points

$$(X_i, f(X_i), f'(X_i)), \forall i = 0, 1, \dots, m$$

Such that

$$X_0 < X_1 < \dots < X_m$$

We find a function S , such that on each sub-interval (X_i, X_{i+1}) , S is a cubic polynomial:

$$S(X) = a + b(X - X_i) + c(X - X_i)^2 + d(X - X_i)^3 \quad (4)$$

The given function f , is interpolated by S , subject to the following conditions:

$$S(X_i) = f(X_i) \quad (5)$$

$$S'(X_i) = f'(X_i) \quad (6)$$

For each (X_i, X_{i+1}) , let $h = X_{i+1} - X_i$.
 We then solve:

$$a = f(X_i) \quad (7)$$

$$b = f'(X_i) \quad (8)$$

$$c = \frac{3}{h^3} [f(X_{i+1}) - f(X_i)] - \frac{1}{h} [f'(X_{i+1}) + 2f'(X_i)] \quad (9)$$

$$d = \frac{1}{h^2} [f'(X_{i+1}) + f'(X_i)] - \frac{2}{h^3} [f(X_{i+1}) - f(X_i)] \quad (10)$$

Each cubic polynomial produces a curve. These curves join smoothly to form the entire yield curve.

3. RESULTS AND DISCUSSION

Figure 1 and 2 show the modeled zero-coupon yield curves for 29th September 2017 and 25th October 2017 respectively. For the purpose of comparison, the figures also show for each respective date the actual yield-to-maturity curves constructed with yield data obtained from the website of FMDQ. Hermite interpolation method is used for the modeled zero-coupon yield curve; while simple (linear) interpolation is used for the actual yield-to-maturity yield curve.

Figure 1: Yield curve on 29th September 2017

Figure 2: Yield curve on 25th October 2017

Even though the modeled zero-coupon yield curves and the actual yield-to-maturity curves have some characteristics in common and portray the same general yield levels, there are some differences when watched closely. The actual yield-to-maturity curve tends to be more linear than the modeled zero-coupon curve. These are shown more clearly by Figure 3 and 4 which plot interpolated yields against the benchmark maturities. A major possible effect which might result from relying on the linearly interpolated curve is underpricing and overpricing of corporate bonds (due to overestimation and underestimation of government yields respectively). The linearly interpolated actual yield-to-maturity curve might also not show the dynamics, shape and trend of the underlying

(zero-coupon) yield curve of the market. For instance, while the modeled curves show higher yields at the short ends and lower yields at the long ends, the linearly interpolated yield-to-maturity curves show otherwise (Figure 3 and 4). This consequently has the tendency of miscommunicating the underlying investor expectations of the macroeconomic environment.

Figure 3: Yield curve on 29th September 2017 (Benchmarks)

Figure 4: Yield curve on 25th October 2017 (Benchmarks)

4. CONCLUSION AND RECOMMENDATION

The results show that the yield-to-maturity curve used by the Nigerian bond market generally appears flatter and more linear than the modeled zero-coupon yield curve. Thus, in addition to the problem of reinvestment risk, linearly interpolated yield-to-maturity yield curve also has the tendency of overpricing and underpricing bonds. It could also have the tendency of miscommunicating the underlying dynamics of interest rates in the bond market and investor expectations about the macro-economy.

We recommend that, in addition to the yield-to-maturity yield curve, the Nigerian bond market adopts a zero-coupon yield curve constructed with continuously differentiable method of interpolation.

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