Assessing Contingent Convertible Bonds for Bank Recapitalization in Nigeria

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This study estimates the parameters of credit derivatives, equity derivatives and structural models for bank recapitalisation in Nigeria by employing contingent convertibles (CoCos) and using the Nigeria Treasury Bill rate for 2009 as the risk-free rate, estimated recapitalisation requirements for the banks as at 2009 and relevant banks' share prices for 2008 and 2009. The study finds the structural approach as the preferred model for CoCo pricing, as it reported the least pricing errors and also builds asset values of the banks from publicly-available quoted stock prices as well as deposit components of bank's balance sheet information. The study also finds that CoCo bonds are likely to be fully subscribed when issued given the high stock price volatility coupled with high credit spreads in Nigeria. The paper suggests that CoCos could have been issued by the banks to recapitalise themselves without the need for regulatory actions. Therefore, usage of CoCos by banks can reduce the possibility of a bailout with public funds and lessen regulatory actions, if properly implemented, to boost the troubled banks' capital.

Keywords: Contingent convertible bond, bond pricing, structural model, equity derivatives, credit derivatives.

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1.0 Introduction

Contingent convertible (CoCos) bonds or CoCos have been proposed as potential mechanisms for bank recapitalisation so as to enhance financial stability (Avdjiev *et al.* 2017). CoCos are fixed income instruments that can be transformed into equity when a bank's capital is below some predefined level or when a trigger is breached (Chen et al. 2013). Both CoCos (a nonresolution/going-concern tool) and bail-in (a resolution/gone-concern situation tool) can boost a failing bank's capital through the conversion of bonds to equity so that the holders of such in-

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struments bear the recapitalisation burden (Bundesbank, 2018). CoCo exists as an accessible and an existing capital to banks during crises because, a bank will have difficulty raising new equity. They are therefore, ideal capital instruments that fulfil new statutory requirements as going-concern instruments. According to Avdjiev *et al.* (2013), they need to possess the following three characteristics in order to achieve that objective. First, there is a need for CoCos to readily act as cushion against losses before or when a bank becomes insolvent. Second, the ability to withstand losses has to be based on the capital base of the bank that will issue the bond. Finally, CoCos should be designed so as to withstand attempts to influence their prices and other undesired speculative activities.

As a new type of bank capital, CoCos have provided a very convenient means of resolving the issues that worry policy makers on strengthening a bank's balance sheet where public funds cannot be used. The Capital Requirements Directive 4 (CRD4) proposal has specified the conditions for CoCos to be suitable as additional Tier 1 Capital. Basel III and the Independent Commission on Banking-Vickers (ICB-Vickers) report have all supported the use of CoCos as contingent capital structures (Boermans and van Wijnbergen, 2018). Flannery (2014) propose the inclusion of considerable CoCos to replace some equity used to satisfy statutory capital adequacy ratios. In addition to Basel III, CRD4 and the ICB-Vickers regulations, other regulators that supported bank capital recapitalisation using CoCos without public funds include the European Banking Authority (2011) and the Swiss Commission of Experts (2010).

CoCos are also recognised by financial institutions, in addition to academics and regulators, as efficient means to enforce countercyclical regulation. Banks prefer CoCos to equity for several reasons (Pazarbasioglu *et al.*, 2011). First, the issuance of CoCos does not alter corporate control because they do not necessarily dilute the source of capital for current shareholders. Second, they can be cheaper if the interest expense is tax deductible. Third, CoCos can be used as Pillar 2 capital in supervisory stress tests. Specifically, CoCos provide a means of achieving the requirements of Basel III such that the CoCos will convert into equity in when the bank is experiencing difficult and needs more capital. Fourth, they can enhance the liquidity of the bank during periods of stress. Fifth, CoCos give incentives to the bank shareholders and management to enhance the bank's risk management for fear of CoCos being triggered.

Despite the global appeal, CoCos were not considered as a better alternative to bailout in resolving the crisis that rocked Nigeria financial system during the 2007 to 2009 global financial crisis. The cost of bailout of the 2007-09 crisis was more than US$8.5 trillion (Alessandri and Haldane, 2011). Major banks around the world were rescued from the crisis with funds of over US$1 trillion. The Nigerian financial system was not spared as the 2008 banking crisis led to capital injection of N620 billion into 10 banks by the Central Bank of Nigeria (CBN), in the form of a subordinated loan (Sanusi, 2010; Sanusi, 2012a). Furthermore, N4.7 trillion of public funds was used by Asset Management Corporation of Nigeria (AMCON), as at 2011, to purchase toxic bank assets and recapitalize banks (Sanusi, 2012b)[2]. Effectively, the 2007-09 global financial crisis as well as the 2008 Nigerian banking crisis were resolved or bailed-out using public funds. CoCos are new to the Nigerian financial system and perhaps coupled with their pricing complexity, have had limited applicability in the context of the domestic banking sector.

The main contributions of this study are three-fold. First, the understanding of CoCos could greatly enhance the toolkit for resolving banks without recourse to public funds in Nigeria. The main issue of the recapitalization is how to price the CoCos by deciding on the main parameters required to issue them. Recapitalization comes only after the decision of pricing and structuring of the CoCos is made. The paper therefore designs CoCos for three banks by deciding on the

[2]In Nigeria, bank failure resolution is the responsibility of the Nigeria Deposit Insurance Corporation (NDIC) and CBN based on the powers accorded the two institutions by the BOFIA 1991 as amended, CBN Act 2007 and NDIC Act 2006. These Acts granted power to the NDIC to carry out the following resolution options: Open Bank Assistance; Depositor Reimbursement; Purchase and Assumption; Bridge Bank Mechanism; Assisted Mergers and Purchase of Assets (NDIC, 2009 & NDIC, 2013). The BOFIA Act enables CBN to perform Open Bank Assistance, act as the Lender of last resort or transfer a bank to NDIC for recapitalisation or any other resolution measures. AMCON, through its Act, has been empowered to Purchase NPLs and recapitalize distressed banks while the Ministry of Finance is the Guarantor of the CBN, therefore the Guarantor of the Lender of Last Resort.

main required parameters that include the conversion rate, appropriate trigger type & level and the yield of the bond. These three Nigerian banks were initially resolved in 2011 using the bridge-bank mechanism. By using the CoCo recapitalisation, bank failure resolution using public funds could be effectively avoided in Nigeria. Second, this paper contributes to the literature of CoCos structuring by employing the credit and equity derivatives as well as structural methods to estimate key parameters required for CoCo pricing in Nigeria. Through the evaluation of the three CoCo pricing models empirically, the paper has extended the literature towards a common or generally accepted modelling for practitioners and academics. These methods are then evaluated based on their applicability and underlying assumptions. Third, specific policy implications for the Nigerian financial system regulators are provided to derive a bank failure resolution using CoCos.

The rest of this paper is categorised into six sections. Section 2 reviews relevant literature covering both theoretical and empirical concepts including the structure and pricing of CoCos. Section 3 discusses some CoCo issuances and CoCo market share while section 4 presents the methodology used for the study. Section 5 presents the data used for the study, implements the chosen CoCo modelling methodologies, discusses the results and their sensitivity analysis. Section 6 concludes.

2.0 Literature Review

A convertible bond is a bond which can be transformed to a fixed quantity of shares of stocks of the company that issued the bond or equivalent value of cash (De Spiegeleer *et al.* 2014). There are different types of convertible bonds. A CoCo, the focus of this paper, is a convertible bond that readily changes from a bond into common stock when some pre-set trigger is activated at an agreed ratio before the expiration of the bond. It should also be noted that CoCos are different from conventional convertible bonds because they possess features of both bonds and equity. Another difference between CoCos and traditional convertible debentures is that in the latter, the conversion is triggered by the bondholder, while in the former, it is triggered automatically without any delay once the stated conditions are fulfilled (Bundesbank, 2018).

It is worthy of note that there is no single generally accepted standard methodology for structuring CoCos (Avdjiev *et al.* 2013). Rather, the choice of the features and parameters of the CoCo should be based on the bank‘s condition. It is therefore vital to understand what constitutes CoCos before they can be structured. In the literature review, the paper presents the theory of structuring CoCos, reviews some selected pricing models and briefly reviews the empirical literature.

2.1 Theoretical Premise for Structuring CoCos

De Spiegeleer *et al.* (2014) and Calomiris and Herring (2011) discuss the structure of a CoCos that comprises three main constituents: the predefined level or trigger which when breached the CoCo is converted to equity so that the bank's capital is increased, the ability to absorb losses, and the underlying host instrument.

2.1.1 The Trigger Event

The choice of the type and feature of trigger is very essential in structuring CoCos. A suitable trigger has to be correctly structured, converted or issued at the right time with detailed valuation of the bank issuing the CoCo (Calomiris and Herring, 2011). Triggers can be either mechanical or discretionary. The mechanical trigger contains a trigger variable with an associated level. The variable can be based on a particular bank or systemically-defined across the whole industry. In the case of the discretionary trigger, the regulator decides when to convert, write down and any other critical decision required to price the CoCo.

According to De Spiegeleer and Schoutens (2011a), the 6 essential criteria for an optimal trigger event are objective, fixed, clarity, public transparent, stable and regularly updated. The clarity condition ensures that the bond has the same meaning in all countries CoCo is traded while the objective condition makes sure that the process of conversion to equity is well understood at the date of issue and is detailed in the prospectus. The remaining four conditions ensure that the trigger is stable and does not change arbitrarily (the fixed condition), clear for all that are interested (the public) and updated continuously (regularity) so that investors can evaluate the CoCo's parameters at all times (transparency).

A CoCo can have a single or several triggers. Common single triggers include market measures like stock price, accounting ones such as Core Tier 1 ratio or regulatory where the decision of when conversion takes place resides with the supervisory body according to assessment of the bank's solvency status.

For accounting triggers, the CoCo is converted whenever an accounting ratio, like the Common Equity Tier 1 (CET1) common equity ratios or leverage ratios, falls below a specified threshold. The trigger is market-based when the CoCo is written down or converted as a result of the share price of the issuing bank falling below some prescribed level, usually set less the share price at issuance. Accounting-value triggers have the limitations of being lagging indicators of the bank's balance sheet because they are not considered to be forward-looking and are only available at low frequencies like monthly or quarterly basis instead of hourly or daily occurrences (Flannery, 2002). In this case, CoCo investors can possibly stay uneducated about key information like the trigger level for long time periods. Also, Flannery (2002) and Skinner & Ioannides (2011) argue that accounting triggers could be erratic or inaccurate as accounting variables can be influenced by the banks and sometimes produce imprecise estimates. For example, accounting ratios produced high CET1 ratios before the 2007 financial crisis which were later found to be incorrect.

An ideal and simple representative of market trigger is the stock price of a bank. The lowest rate of the market value trigger is obtained as the fraction of the stock market capitalisation of the bank to its assets (Sundaresan and Wang, 2011). Market trigger is available at high frequencies like hourly and daily and are considered to be forward-looking. However, difficulty of pricing and possibility of the share price being manipulated by market players are some disadvantages of the market-value trigger (Avdjiev *et al.* 2013). The academia prefers market-value to accounting triggers because they satisfy all the outlined properties (De Spiegeleer and Schoutens, 2011a). This could therefore reduce balance sheet manipulation and the need for regulatory intervention or forbearance, as the case may be.

Bank supervisors decide when regulatory trigger (also called non-viability trigger) can be activated based on the strength of the issuing bank's balance sheet. Using this trigger, bank supervisors have the power to trigger a CoCo so as to prevent the issuing bank's insolvency or further decline its existence. It is challenging to price CoCos using regulatory trigger because when conversion should take place cannot be easily determined in a transparent manner but at the choice of the regulator (Nordal and Stefano, 2014). Furthermore, Nordal and Stefano (2014) state that regulatory forbearance, where regulators may wait longer than necessary before triggering conversion supports not using the regulatory triggers.

Some regulators like the Swiss Commission of Experts (2010) prefer either the non-viability or accounting to market triggers. This may be supported by the possibilities of profitable stock price manipulation (Flannery, 2009). However, Bloomberg (2009) argue that a CoCo with a single accounting trigger can be effortlessly manipulated; it is also neither transparent, public nor frequently updated. According to MacDonald (2010) and Rudlinger (2015) given that stock prices are much more regularly updated and more objective than accounting ratios, they could be less susceptible to manipulation.

Multi-variate trigger, another type of trigger, accomplishes the switch of the CoCo into stocks by relying on more than a single trigger stipulation (De Spiegeleer and Schoutens, 2011b). For the multi-variate triggers, both the banking system and individual bank measures are considered as enhancement to only individual triggers like a single accounting trigger (MacDonald, 2010). When a CoCo possesses more than one trigger, then the ability to absorb losses becomes active when any of the triggers is breached. Once the capital of a bank falls lower than a certain level as a percentage of its risk-weighted assets, then the accounting trigger is activated (Avdjiev *et al.* 2013). In some cases, the bank or the supervisors' of the firm can set the trigger at their discretion. The recapitalization of banks with solvency problems using the multi-variate trigger is possible when the banking system is either stable or in crisis.

2.1.2 The Loss-Absorption Mechanism

It is the next main feature of every CoCo after the trigger event. The loss-absorption mechanism deals with transforming debt to equity or non-reversible principal write-down so that the issuing bank's equity can be enhanced (Flannery, 2009)[3]. In the first case, the CET1 of a CoCo is boosted because the debt is converted to equity CoCo at some conversion rate that has been pre-defined. In such a case, the loss absorption mechanism can be tied to the stock price of the bank when the trigger is breached; a pre-stated price that is usually the stock price when it is issued. It can also be a mixture of the two.

The write-down of a CoCo's principal could be either full or partial. The most common write-down among CoCos is the full one. The conversion ratio C_r is defined as the number of shares that one gets for each converted bond. Given the face value N, the conversion price C_p can be defined as the price that the underlying shares can be purchased when the trigger event occurs.

2.1.3 The Host Instruments

This is the underlying contract into which the CoCo was embedded such as junior bond, senior debt or a perpetual preferred security. The host instrument could therefore be debt or a convertible bond. As described by Stamicar (2016), CoCos are eligible as either Additional Tier 1 (AT1) or Tier 2 (T2) capital in Basel III. T2 capital is a gone-concern capital because it enables loss-absorption while liquidating a bank. It is also lower in seniority to senior debt and deposits but higher than T1 capital (Stamicar, 2016). For CoCos to meet the requirements of AT1 capital, they must absorb losses and prevent insolvency as a going-concern contingent capital.

2.1.4 Pricing Contingent Convertible Bonds

The combined features of both equity and fixed-income present in CoCos make their pricing challenging. According to Erismann (2015) and Stamicar (2016), CoCo pricing can be divided into three categories: credit derivatives or reduced form approach, equity derivatives model and structural approach.

[3]For further details, see De Spiegeleer *et al.* (2014) and McDonald (2010).

In the credit derivatives approach, CoCos are regarded as bonds that can default while cash is the final payoff (see De Spiegeleer and Schoutens, 2011a; Duffie and Singleton, 2003). For the equity derivatives approach, the pricing of CoCos involves looking for solutions of a portfolio that reproduces the final payoff which is viewed as long position in share prices that are knocked in once a trigger is breached. CoCos can be priced using barrier options in this approach (see Rüdlinger, 2015; De Spiegeleer and Schoutens, 2011a).

The structural approach posits that once a firm's asset value falls below its liabilities, the firm can be considered to have defaulted. Using the specified stochastic process for the assets and liabilities, the structural approach estimates the probability of default of the firm. This approach was used to price CoCos by Albul *et al.* (2010), Chen *et al.* (2013), Krishnan and Jacoby (2012), Pennacchi (2010), De Spiegeleer & Schoutens (2011a) and Glasserman & Nouri (2012).

2.2 Empirical Literature

Wilkens and Bethke (2014) carry out an empirical review of CoCo pricing models focussing on their appropriateness for specific scenarios and instruments. The study of CoCos issued by major banks showed that the 3 pricing approaches were found to be ideal for CoCos bond prices that have been offered. However, the study reveal that the equity derivatives model is the most appropriate for structuring CoCos as well as managing the associated risks in practice due to its simplistic parameterisation and interpretation. They also find that although the equity derivative model was the worst performing model in assessment of model fit, it accomplishes the best performance in their hedge assessment. The study suggest further empirical study due to the relative short period of CoCos offered as well as the data used for the analysis.

Erismann (2015) study CoCo pricing using four models: the structural approach, credit derivative and equity derivative approaches and a credit default swap[4] model

[4] A credit default swap (CDS) is a financial derivative or contract that allows an investor to offset his or her credit risk with that of another investor. In this contract, one party

devised by the investment bank J.P. Morgan. It was found that for model complexity, the credit derivative model has the least while the equity derivative model the highest, whereas the structural approach suffers from data assembly and parameterization. It was also found that all the models overestimated the risks in CoCos in comparison to what has been observed in practice and that the structural model reported the least pricing errors and therefore preferred.

Liebenberg *et al.*, (2018) propose Call Option Enhanced Reverse Convertible (COERC), a variation of CoCo for African banks. COERC are bonds that transform to equity when the bank's share of capital drops lower than a certain level. One of the main reasons for choosing COERCs is because issues associated with market-based triggers due to influence and panic can be avoided by banks in using them. The study supports using CoCos to encourage counter cyclicality for banks' capital structure. However, for the African market, the study suggested modifications to the COERC structure like altering the coupon payment mechanism of the COERCs issued by banks in Africa so that they stop paying coupon to investors, or decrease the amount coupon payments.

A study by Avdjiev *et al.* (2017) find that CoCos with mechanical triggers and Additional Tier 1 (AT1) designation as well as those that convert to equity led to reduced bank fragility through lowering of its credit risk. They also note that CoCos that possess only regulatory triggers do not seem to have any impact on the bank's credit risk and except for those with principal write-down and high trigger value, CoCos don't seem to have any statistically significant impact on share prices.

In a review of CoCos issued by European banks between January 2009 to June 2014, Nordal and Stefano (2014) note that 37 banks had accounting triggers based on capital adequacy ratios, the range of the trigger levels was between 2% and 8.25% out of which majority of these issues (59%) have a trigger in the range of

makes payments to the other and receives in return the promise of compensation if a third party defaults. It may involve municipal bonds, emerging market bonds, mortgage-backed securities or corporate bonds. The credit default swap model prices CoCos using the CDS arguments where the value of the CDS to a buyer is going to be the risk neutral value of the protection minus the risk neutral value of the premiums.

5%-5.25% and 5.125% are more common than 5% trigger. The 5.125% trigger are possibly due to Basel III requirements of additional Tier 1-qualifying capital having a trigger not less than 5.125%. The study state that market-based trigger through equity conversion, as used in the first CoCo issued by Lloyds, though still used to structuring CoCos, has lost traction and less used than accounting-based ones.

3.0 Some CoCo Issuances and CoCo Market Share

This section summarizes global CoCo issuances, market share and potentials. CoCo bonds were initially issued mainly in Europe (Bundesbank, 2018) that could be because, as previously stated, CoCos have qualified as regulatory capital in Basel III since 2013. CoCos of 9.6 billion euro was first issued in 2009 by Lloyds bank followed by Intesa Sanpaolo, Rabobank, Unicredit and Yorkshire Building Society in 2010 whose total face value was 2.9 billion euro (Nordal and Stefano, 2014).

Table 1 provides some key details of the earliest CoCo issuances. From the table, Lloyds had the largest issuance size, followed by Barclays, then Credit Suisse with the least issued by Rabobank. All the CoCos issued had 10 year maturity except Lloyds with 10-20 years while Credit Suisse had 30 years. It should be noted that the Trigger is 7% CET1 or 7% Equity/Risk-Weighted Assets (based on Basel III) for the banks, except Lloyds that is based on 5% Core Tier1. It is worthy of note that not only Global-Systemically Important Banks (GSIBs) offer CoCos as shown in the table. Rabobank is not a GSIB and was one of the early issuers of CoCos.

Table 1: Description of some of the early CoCos

	Lloyds	Credit Suisse	Barclays	Rabobank
Issue Size	GBP 7 bn	$2 bn	$3 bn	€1.25 bn
Issue Date	1st Dec, 2009	24th Feb, 2011	21st Nov, 2012	12th March, 2010
Maturity	10–20 year	30 year	10 year	10 year
Yield at Issue	Libor +7–8%	Libor + 5.22%	Libor + 6.2%	Libor + 3.5%
Coupon	Exchange for 1.5–2.5% increase of the coupon of CoCo	7.88%	7.63%	6.88%
Conversion Price	59 pence (= stock price during CoCo's issue)	max(20USD, 20CHF,	Full (100%) Write-Down	Partial (75%) Write-Down
Trigger Level	5% Core Tier 1	7% CET1	7% CET 1 ratio	7% Equity capital/RW

Source: De Spiegeleer *et al.* (2014)

Nordal and Stefano (2014) review CoCos issued by European banks from January 2009 to June 2014. They note that 37 banks from twelve countries issued CoCos with total face value volume of approximately 74 billion euro via 102 issues. They further note that most of the 11 large issuers (73%) were classified by the Financial Stability Board as Global-Systemically Important Banks. It was also stated that G-SIB issuers hold a notable 58% share of the global CoCo market. Up to the review period, the authors further state that on bank-by-bank basis, the biggest issuance of outstanding CoCos were by Lloyds and Credit Suisse with 14% and 12% share of the European market, respectively. The third place was jointly occupied by Barclays and UBS with 11% of the market share. Considering the two big Swiss banks, Nordal and Stefano (2014) state that Credit Suisse and UBS have issued CoCos totalling 23% of all CoCos issued by European banks. In terms of currency, it was reported that the issuances in the CoCo market were mainly through Euros and US Dollars.

By the end of 2017, 398 CoCo bonds were issued in Europe with a total volume of 230 billion euro with the UK banks having the largest issuances, then Swiss, French and finally Spanish banks (Bundesbank, 2018). In the same German central bank report, the regulator state that out of these European CoCo bonds issuances, European Union had 285 with a total volume of 193 billion euro out of the 230 billion euro[5]. The central bank also note that European CoCo bonds were then mostly in the hands of investors outside Europe, then held by mutual funds found in Ireland and Luxembourg.

Furthermore, capital was raised through CoCos issuance by 64 European banks which were mostly British and Swiss (Boermans and van Wijnbergen, 2018). They also note that European banks issued three times the total amount of CoCos against those from 2012 to 2015 that achieved a record value of 157 billion euro. According to them, banks' desire to structure CoCos was burgeoning in Europe due to the proliferation of new rules and regulations as a result of the 2007-09 financial crisis. For instance, banks have to respond to the European implementation of the Basel III Accord, the European Bank Recovery and Resolution Directive and the European Banking Authority requirements of the liquidity coverage ratio for banks.

Avdjiev *et al.* (2017) report that global data as at 2015, by Bank for International Settlements, showed that CoCo bonds valued at 522 billion euro was from 731 issues, out of which 39% were conducted by European banks. $713 million was the average CoCo issued and the value of the issues was in the range of $2 million to $7 billion. The authors further note that 39% of the issuances can be credited to the European market followed by banks from non-European advanced economies with 14% while emerging market economies had over 46% of the CoCo market by the end of 2015. The early part of the sample, according to Avdjiev *et al.* (2017), was mainly located in advanced European countries especially the UK and Switzerland, while the last part of the sample contains issuances by non-European advanced economies like Australia, Japan, and Canada, which steadily picked due to the implementation of Basel III. CoCo issuance by banks in Emerging Market economies was moderately low until the last years of the sample, when Chinese banks became active issuers of CoCos. However, a prominent non-appearance from

[5]Note that Europe and European Union are distinct entities according to the German central bank report. It should be noted that Europe is a continent that has 45 states/countries while European Union is a political and economic association of some countries in Europe, comprising of 27 countries. The term "Europe" cannot interchangeably refer to European Union because not all the countries of Europe are part of the European Union (e.g Norway, Switzerland, Ukraine, etc.)

register of CoCo-issuing countries is the United States.

Avdjiev *et al.* (2017) also describe CoCo issuances according to currencies. The authors state that banks usually issue CoCos either in their individual home currencies or in US dollars. Almost all CoCos issued in Australian dollars, British pounds, Canadian dollars, Chinese yuan and Japanese yen were issued by banks from the corresponding currency-issuing countries. It was also stated by the authors that euro area banks issued about two thirds of the $84 billion in euro-denominated CoCos. It was further noted that 28% of global issuance, $148 billion worth of CoCos, was US dollar-denominated.

Boermans *et al.* (2014) state that over 20 European banks had issued more than 100 CoCos within 2012 to 2014. The majority of CoCos, according to the authors, were issued by British and Swiss banks, while in 2013, Danish, German, French, Italian and Spanish banks have all issued CoCos to raise capital. Boermans *et al.* (2014) further report that the total volume of CoCo issuances reached its highest level of 28 billion euro in the first six months of 2014. The reason given for the rising CoCo issuances in Europe, according to the authors, include the search for yield and investors' readiness to take extra risks where the effective yield on CoCos was 8.3% at end-2013 against 6% on other high-yield bonds and the new set of rules and regulations on capital requirements for banks like Basel III Accord and the European Capital Requirements Regulation that allowed CoCos to be used as an additional bank capital. Other reasons given by the authors include the fact that European banks issued CoCos to enhance their capital base towards the comprehensive assessment carried out by European Central Bank and that CoCos are less restrictive than new shares. For instance, CoCos do not result in capital dilution for existing shareholders.

4.0 Methodology

4.1 CoCo Modelling using Structural Model

The structural approach, introduced by Merton (1974), was based on the Black-Scholes option pricing framework and it involves modelling the assets on a bank's balance sheet using a suitable stochastic process. It should be noted that, this approach considers the total value of the bank's assets to be equal to the sum of its capital instruments. Therefore, the value of the bank's assets should be equal to the sum of the bank's deposits, CoCos, senior bonds and book value of equity (De Spiegeleer & Schoutens, 2011a and Glasserman & Nouri, 2012).

The structural models explicitly capture the trigger event, the credit derivatives models view CoCos as carrying credit risk as an integral feature like conversion through the trigger while equity derivative models regard the stock price as representing the bank's financial condition.

In the classical structural Merton credit risk model, the value of any firm is based on the Geometric Brownian motion (GBM) given in (1). Let the total value of a bank be V, its continuously compounded return on V given as μ. Also, let the volatility of the bank's assets be σ_v while dW is a standard Wiener process.

The GBM describes the random behaviour of the asset price level V_t over time

$$dV = \mu V dt + \sigma_v V dW \tag{1}$$

The Merton model considers a bank that has issued a bond that will expire at time T and the bank's activities are funded with equity E_T. Therefore, the value of equity is the price of a European call option on the bank's assets (A) minus its net liabilities (D). The call option is priced by the Black-Scholes-Merton formula. This is specified in (3).

$$E_T = \max(A_T - D, 0) \tag{2}$$

However, according to the put-call parity, the bank's value of its debt is equivalent to the value of a risk-free discount bond with put option value subtracted. The Merton model defines the bank' equity value as

$$E_T = AEN(d_1) - e^{-rT} DN(d_2) \tag{3}$$

According to (3), E is the bank's equity market value, the risk-free rate is r while the cumulative standard normal distribution function is $N(\cdot)$. d_1 and d_2 can be specified as

$$d_1 = \frac{\ln(^{A_T}/_{D}) + (r + 0.5\sigma_v^2)T}{\sigma_v\sqrt{T}} \tag{4}$$

where

$$d_2 = d_1 - \sigma_v\sqrt{T} \tag{5}$$

From Ito's Lemma,

$$\sigma_E = \left(\frac{V}{T}\right)\frac{\delta E}{\delta V}\sigma_v \tag{6}$$

From the Black-Scholes model we obtain that $N(d_1) = {}^{\delta E}/_{\delta V}$ and

$$\sigma_E = \left(\frac{V}{E}\right)N(d_1)\sigma_v \tag{7}$$

The probability of default is the probability that the call option is not exercised as given in (8)

$$PoD = N\left(\frac{\ln(^{A_T}/_{D}) + (r - 0.5\sigma_v^2)T}{\sigma_v\sqrt{T}}\right) \tag{8}$$

Distance-to-default (DD) measures the number of standard deviations the expected asset value is away from the default. Therefore, a high DD value implies a low default probability. A low or $0.0DD$ or even negative means that the bank is extremely likely to fail unless the asset value improves. DD is related to Probability of Default (PoD) and given as

$$PoD = N(-DD) \tag{8b}$$

Derivation of Implied Credit Spread from the Merton Model

A credit spread refers to the difference in yield of two bonds of the same maturity but with dissimilar credit rating. For existing risk-free rate and the market value of today's debt B_0, then:

$$B_0 = A_0 - E_0 \tag{9}$$

Recall from (3) that $E_T = AEN(d_1) - e^{-rT}DN(d_2)$. Therefore,

$$B_0 = A_0[N(d_1) - LN(d_2)] \tag{10}$$

Leverage, L, can be obtained from (6) and (7) as

$$L = \left(\frac{De^{-rT}}{A_0}\right) \tag{11}$$

Let y be the yield to maturity, then s, the implied credit spread of the Black-Scholes model can be solved as

$$s = \ln\left[N(d_2) - \frac{N(-d_1)}{L}\right] \Big/ T \; from \; y - r = s \tag{12}$$

4.2 CoCo Modelling using Credit Derivatives

In a reduced-form approach, default probability is stochastic, described by a Poisson process and is controlled by a hazard function λ. For time short time t, λdt is the default probability by a bank that issues a bond whose default occurs within time interval $[t, t + dt]$. P_{serv} is the probability that the bond survives between time t and T and is given as $\exp(-\lambda(T - t))$. Similarly, the default probability, P_{def} , is the default probability of the bond from time t to T and is given as $1 - \exp(-\lambda(T - t))$, with T as Maturity. The equations in this section are given in De Spiegeleer *et al.* (2014).

When there is a default, the bond investors are expected to recover some portion of the face value N of the bond. The recovery rate in this case is denoted as π while the loss the investor suffers is calculated as $(1-\pi)N$. However, credit spread is traditionally used by investors to include default risk of a bond. Therefore, the credit spread CS and default intensity (hazard function) λ of a bond are related by the following equation

$$CS = (1 - \pi)\lambda \tag{13}$$

Equation 13 is a very important equation that links together credit spread, credit spread and recovery rate. This equation enables modelling the trigger event of a CoCo that converts into shares similar to default in corporate debt as an extreme event, which is used in modelling hitting the CoCo trigger.

The probability of default (PD) and the loss given default (LGD) are related to the credit spread according to Allen *et al.* (2009) by the following equation:

$$CS = PD \times LGD \tag{14}$$

It is well-known that expected returns of a risky asset give the equivalent of the return of a risk free rate in the absence of arbitrage. Therefore, a risky debt's observed yield can be broken down into the sum of a risk-free rate and a premium on risk.

For CoCo or contingent debt, the default intensity λ given in (13) is substituted with a CoCo trigger intensity $\lambda_{Trigger}$ while π_{co} is the CoCo recovery rate. We can therefore obtain the value of the credit spread on CoCo or contingent debt using the following credit triangle:

$$CS_{co} = (1 - \pi_{co})\lambda_{Trigger} \tag{15}$$

It should be noted that the loss suffered by the CoCo can be pre-specified for CoCos that possess a write-down mechanism. $\pi_{co} = 0$ for a full write-down on a CoCo. However, for CoCo with a conversion in shares, the losses will be based on the level of the share price $S*$, usually unknown, when the trigger is hit.

Recall π_{co} is known as the recovery rate for a particular CoCo bond. The loss for the Coco,Lo_{co}, is given as:

$$N(1 - \pi_{co}) \tag{16}$$

Recall S^* is the trigger Stock price and P_c is the conversion price per share, then the recovery rate when the CoCo is triggered is the ratio of trigger stock price and the conversion price, that is $\pi_{co} = S^*/P_c$. Therefore, CoCo credit spread can also be written as

$$CS_{co} = (1 - \frac{S^*}{P_c})\lambda_{Trigger} \tag{17}$$

Obviously, there is no loss suffered on the investment if both the conversion price and the share price observed at the moment of the trigger are equal.

Recall $P_{def} = 1 - \exp(-\lambda_{Trigger}(T - t))$, therefore

$$CS_{co} = \frac{1}{T - t}\log(1 - P_{def}(1 - \frac{S^*}{P_c})) \tag{18}$$

Let $\phi(x)$ be the probability that a random variable X, that follows a standard normal distribution and takes a value smaller than x. Let σ be volatility, S the current share price and P^* the probability of hitting the trigger during the life of the CoCo and is given as

$$P^* = \left(\frac{\log\left(\frac{s*}{s}\right) - \mu\left(T-t\right)}{\sigma\left(T-t\right)^{(0.5)}} \right) + \left(\frac{s*}{s}\right)^{\frac{2\mu}{\sigma^2}} \phi \left(\frac{\log\left(\frac{s*}{s}\right) + \mu\left(T-t\right)}{\sigma\left(T-t\right)^{(0.5)}} \right) \tag{19}$$

where $\mu = r - q - \frac{\sigma^2}{2}$, $r =$ risk free interest rate, continuously compounded and q=continuous dividend yield. Therefore, $\lambda_{Trigger}$ can also be written as $-\log(1 - P^*)T$.

It is worthy of note that the probability of hitting the trigger given as (19) is modelled using the Black–Scholes setting as used in Section 4.1.

4.3 CoCo Modelling using Equity Derivatives

The equity derivatives model used in this paper is based on GBM using Black–Scholes assumption in order to obtain a closed form solution[6]. De Spiegeleer *et al.* (2014) present the final payoff of a CoCo into the bond's face value and a component that occurs based on an actual trigger during a bond's life. In the equity derivatives approach, the CoCo is priced by solving for a portfolio that replicates the CoCo's cashflow. It is based on the assumption that a CoCo can be broken down into a bond part and another part consisting of a derivative contract on the stock of the CoCo issuer.

Let D be the Face value of CoCo, N is the Number of shares to CoCo holders at conversion and KIF traders are left with the residual value of their stocks discounted at q as the cost of carry. To price CoCo using the equity derivatives approach, we consider the cash flow of a portfolio consisting of a long position in Bond and a long position in N KIFs that replicate the cash flow of the CoCo. Therefore, to price a CoCo using a closed-formula, a zero-Coupon CoCo is the sum of Zero-Coupon Corporate Bond (B) and Knock-In Forwards(KIFs):

$$CoCo_t = value(B + KIFs)_t \tag{20}$$

[6] A closed form solution is an expression for an exact solution given with a finite amount of data. A solution is in closed-form if we can solve a given problem in terms of functions and mathematical operations from a given generally-accepted set.

Equation (20) can therefore be written as

$$CoCo_t = e^{-r(T-t)}D + KIF_t \tag{20a}$$

The Zero-Coupon Corporate Bond part of Equation (20a), $e^{-r(T-t)}D$, is computed using the risk free rate, r, for time period $T-t$.

On the other hand, the price of a KIF is the sum of a short exposure in a knock-in[7] put (KIP) and a long exposure in a knock-in call (KIC):

$$KIF_T = KIC_T - KIP_T \tag{21}$$

Let S, σ, $\phi(x)$ and μ be parameters described in Section 4.3. Both KIC and KIP share the same strike P_c and barrier prices S^*. KIC and KIP are given as

$$KIC_t = S_t e^{-q(T-t)} \left(\frac{s*}{s_t}\right)^{\frac{2\left(r-q-0.5\sigma^2\right)}{\sigma^2}} \phi\left(\frac{\log\left(\frac{s*}{s}\right) - \mu\,(T-t)}{\sigma\,(T-t)^{(0.5)}}\right)$$

$$-P_c e^{-r(T-t)} \left(\frac{s*}{s_t}\right)^{\frac{2\left(r-q-0.5\sigma^2\right)}{\sigma^2}} \phi\left(\frac{\log\left(\frac{s*}{s}\right) + \mu\,(T-t)}{\sigma\,(T-t)^{(0.5)}}\right)$$

$$KIP_t = P_c e^{-r(T-t)} \phi\left(-\frac{\log\left(\frac{s*}{s}\right) + \mu\,(T-t)}{\sigma\,(T-t)^{(0.5)}}\right) - S_t e^{-q(T-t)} \phi\left(-\frac{\log\left(\frac{s*}{s}\right) - \mu\,(T-t)}{\sigma\,(T-t)^{(0.5)}}\right) \tag{22}$$

Consequently, the CoCo price, as given in Equations (20) and (20a), is:

$$CoCo_t = e^{-r(T-t)}D + N * (KIC_t - KIP_t) \tag{23}$$

The similarity between the equity and credit derivatives approaches is that they are based on a single stochastic process that solves for both the trigger

[7] A knock-in is a type of option contract that only becomes an option when a specified price (barrier) is encountered. Therefore, if the price is never reached, the contract will then not exist. Knock-ins are a type of barrier option while barrier option is a type of contract in which the payoff depends on the underlying security's price and whether it hits a certain price within a specified period. Barrier options usually have cheaper premiums than traditional vanilla options, because the barrier increases the probability of the option expiring worthless. There are two types of knock-in options: down-and-in and up-and-in. In the former, the option is activated only if the underlying security's price falls below a certain level. The latter type of option is activated only after an underlying security's price rises to a certain level. Call option gives you the right to buy while sell gives the right to sell the underlying security.

and the share price. The assumptions about the trigger contingency is the distinction between the two derivatives approaches as well as the structural approach. However, they do not use accounting trigger but rather market-based one. The structural Merton (1974) model uses the market value of assets that can depend on the accounting trigger.

4.4 Selecting the appropriate CoCo pricing approach

A major feature of the three pricing methods is the use of Black–Scholes assumption based on Geometric Brownian Motion (GBM) that log returns on assets are independent and identically normally distributed as well as volatility being constant. These assumptions have been proven to be empirically incorrect given the presence of fat-tails in finance data, volatility clustering and long-term correlated returns as well as the presence of jumps in the prices of some assets. Despite these deficiencies, the Black-Scholes framework has the benefit of enabling analytically closed-form expressions for the model in question. Levy process, instead of GBM, has been suggested to be better models for describing asset or stock price dynamics.

As described in section 4.2, the credit derivatives method is a straightforward approach and very simplistic. The credit derivatives approach is motivated by bonds' features and is priced based on this focus, while neglecting the underlying stock as the major driver of CoCo valuation. Obviously, this is a major limitation. Also, in the credit derivative approach implemented, we calibrated the conversion intensity λ as a deterministic function of time, instead of considering it to be stochastic, λ_t which can be done by incorporating jumps in the model. The assumption of constant conversion intensity variable is for ease and practicality of implementation.

Recall that in the equity derivatives method, the CoCo is divided into bond, forward and options instruments and therefore its cash flows are considered to be more realistic than other methods. Consequently, the CoCo structuring process can be replicated, and the instrument's payoff estimated and investigated. It should be noted that replicating the equity part of the equity derivative model using *knock-in* forwards[8] may not necessarily result in perfect replicates. That is because CoCos, usually subscribed by large institutional investors, can hold a substantial portion of equity share after conversion and then be able to exercise control of the company. The equity

[8]Knock-In Forwards allows the holder whereby to benefit from favourable moves in spot price up to a predetermined limit. If the knock-in barrier is activated, the holder will have to progress with the trade at the strike price. Otherwise, the holder can avail of advantageous move in the spot up to a limit.

derivatives method is therefore a better option than the credit derivatives for pricing CoCos.

The structural credit risk model shares all the flaws of the Black-Scholes approach. However, it has had more theoretical and empirical applications and as reviewed in the literature, the shortcomings of constant volatility and fat-tails have been resolved through the use of stochastic volatility models and price processes that incorporate jumps.

As earlier reviewed, Wilkens and Bethke (2014) show that the 3 pricing approaches were found to be ideal for CoCo bond prices but that the equity derivatives model is the most appropriate for structuring CoCos, was the worst performing model in assessment of model fit but it accomplishes the best performance in their hedge assessment. Also, Erismann (2015) report that the credit derivative model has the least while, the equity derivative model the highest, whereas the structural model reported the least pricing errors and therefore preferred.

The structural Merton model views a bank's liabilities as contingent claims issued against its underlying assets. By obtaining the asset values and asset volatilities from publicly available quoted stock prices and balance sheet information, the structural model produces instantaneous updates of a firm's default probability. Furthermore, the Distance to default (DD), a measure calculated from Merton's model has been used to monitor risks of financial institutions by international organizations and financial authorities such as the European Central Bank. The DD is an important forward-looking indicator that can provide early signs of bank fragility. We therefore, recommend the structural approach as the preferred model for CoCo pricing.

5.0 Empirical Analysis

5.1 Data Description

The study uses data of the three bridge-banks established by the NDIC after the 2009 banking crisis for the subsequent transfer of assets and liabilities of the three insolvent banks (NDIC, 2013).

Prior to the establishment of the bridge-banks, Bank1, Bank2 and Bank3 banks were trading at the Nigeria Stock Exchange (NSE). The daily stock price and market capitalisation of the banks covering the period from 2008 to 2009 were obtained from the NSE and used for the study.

The Treasury bill rate was 3.88 in January 2009, 2.00 in February 2009, 2.53 in March 2009, 3.32 in June 2009 and 4.80 in August and September 2009[9] . Treasury bill rate was obtained from the CBN statistical database and used as the risk-free rate.

Katata and Nwaigwe (2016) estimated recapitalisation required for Bank1, Bank2 and Bank3 banks as N115.04 billion, N80.74 billion and N183.00 billion, respectively. These figures are used as the face values of the CoCos.

Recall that CoCos are bonds that by design transform into equity after a pre-set trigger is hit. According to the Central Bank of Nigeria (CBN, 2011), any bank that has a Capital Adequacy Ratio (CAR) of less than 10%, as the approved minimum CAR, but more than 5% in any month is undercapitalised. The trigger in this case is Regulatory and is activated when the CAR is less than 5% or when the share price is less than half of its value on the specified dates as follows. Bank2's share price was N5.59 for most of 2008 and 2009 but N2.78 on 13^{th} October, 2009 and has estimated volatility of 13.73% obtained using data from 2^{nd} January 2008 to 12th October, 2009. Bank3's share price estimated volatility was estimated to be 58.33% based on daily data from 2^{nd} June 2008 to 20^{th} July 2009. For Bank1, its share price was N9.13 as at 1^{st} February, 2009 but descended to N4.49 on 9^{th} July, 2009 with 65.51% as estimated volatility.

The parameters used for pricing the CoCos to be issued by the three banks are presented in Table 2.

One of the major uncertainties that is required to price the models is volatility. Table 2 shows that the stock price of Bank1was the most volatile during the 2009 banking crisis, closely followed by Bank2 but Bank3 had very low stock price volatility because the share price was fixed or constant for a long period of time.

[9]https://www.cbn.gov.ng/rates/mnymktind.asp?year=2009&month=8

Table 2: Parameters for the CoCos to be Issued by the Three Banks

	Bank1	Bank2	Bank3
Estimated Annual Volatility	65.51%	13.73%	58.33%
Market Capitalisation (₦' Billion)	60.65	33.058	98.76
Total Deposits(₦' Billion)	247.4	178.7	383.3
Total Insured Deposits(₦' Billion)	38.6	59.64	32.33
D(₦): Face value of CoCo	115.04 bn	80.74bn	183 bn
S(₦): Stock price	9.13	5.59 throughout 2008	10.24 as of 31/12/2008
S^*(N): Trigger Price	4.49 as of 7/9/2009	2.78 as of 13/10/2009	4.9 as of 20/07/2009
N : Number of shares to CoCo holders at conversion	D/S*	D/S*	D/S*
T: Maturity of CoCo	10	10	10
r_f:Risk-free interest rate	0.048	0.048	0.048
Recovery rate	0.5	0.5	0.5

5.2 Empirical Results

The aim of this section is to design CoCos for Bank1, Bank2 and Bank3 by selecting the conversion rate, the yield and other necessary variables of the CoCo without recourse to public funds. In this paper, simple data analyses are carried out using Excel, while the main estimations and simulations are performed with Matlab package.

5.2.1 CoCo Pricing Using Structural Models

The first important step in CoCo pricing is to decide what the trigger is, which has been reported in Table 2 together with other parameters. Based on the parameters in the previous section, using total deposits as liabilities, Table 3 presents the parameters estimated using Merton (1974) Structural Model as described in Section 4.1 and equations (1) to (12).

Table 3: Result of CoCo pricing using Structural Model

	Bank1	Bank2	Bank3
Distance to Default	0.81000	4.57000	0.92100
Probability of Default	0.20900	0.00000	0.17900
Yield to Maturity	0.11000	0.05000	0.09000
Implied Credit Spread	0.07000	0.00000	0.04200

As observed in Table 2 with its stock price being the most volatile during the 2009 banking crisis, Bank1 presented the shortest Distance-to-Default as well as having the highest Probability-of-Default therefore the riskiest bank. Consequently, the CoCo yield of Bank1 is the highest out of the three banks with corresponding highest credit spread. Bank3 closely follows Bank1 with the second highest Distance-to-Default and corresponding Probability-of-Default as the next risky bank. Bank2 produced the lowest yield and reported that there is no need for credit spread if CoCo is to be issued.

Note that when the implied credit spread is added to the continuous interest rate, we obtain the total yield of the CoCo that the bank will issue.

5.2.2 CoCo Pricing using Credit and Equity derivatives

Based on the parameters presented in Table 2, Table 4 presents the variables of interest required for issuing CoCo by the three banks using credit (described in Section 4.2, equations 13-19) and equity derivatives approaches (described in Section 4.3).

Table 4: Result of CoCo pricing using Credit and Equity derivatives

	Bank1	Bank2	Bank3
Credit Derivatives Credit Spread	0.06080	0.00100	0.05840
Credit Derivatives Price	0.33700	0.61270	0.34510
Credit Derivatives Trigger Intensity	0.22630	0.00200	0.18860
Credit Derivatives Prob. of hitting trigger	0.89600	0.01940	0.84830
Equity Derivatives Credit Spread	0.01220	0.00030	0.01830
Equity Derivatives yield	0.06020	0.04770	0.06630

Like the result obtained from the structural model, the credit derivatives approach reported the highest credit spread to be by the CoCo of Bank1, then Bank3 and Bank2 has the least but non-zero value. Equity derivatives approach however priced the highest spread and yield to CoCo of Bank3 followed by Bank1 with Bank2 having the lowest non-zero spread.

The credit spread expected from Bank2 is the lowest from the three approaches. For Bank3, the Equity Derivatives approach reported lower credit spread than the Structural Model which also reported lower values than obtained from the Credit Derivatives approach. For Bank1, the highest credit spread was estimated by the Structural Model followed by Credit Derivatives approach with the Equity Derivatives method giving the lowest estimate.

The paper supports the findings of Wilkens and Bethke (2014) that the equity derivatives model is the most appropriate for structuring CoCos due to its simplistic parameterisation and interpretation. However, model accuracy and other germane issues may be overlooked. The study also supports the findings of the Krishnan and Jacoby (2012) and Wilkens and Bethke (2014) as the most appropriate for CoCo pricing by reflecting the most CoCo features but the approach suffers from model complexity.

The two derivative approaches give different prices because there is a difference in what the CoCo holders get for equity and credit derivatives approach at maturity of the bond. For the former, the holder of the bond is rewarded with a forward on the stock that matures. In case of the latter, that is the credit derivatives approach, the holder is rewarded with cash amount, not forward, that is the same as the number of shares multiplied by trigger price at maturity.

5.3 Sensitivity Analysis

This subsection presents the result of the several sensitivity analysis conducted on the variables in the structural approach of CoCo pricing. In the sensitivity analysis, we vary some of the variables while keeping others constant to understand the framework better according to equations 1-12. It should be noted that there is some level of uncertainty when dealing with financial models with respect to the estimated parameters. By changing the input data in the model, we can better understand the model sensitivity as a function of the estimated parameters.

The default probability in the Merton model is a nonlinear function (where the default probability has to be solved iteratively using optimization, in this paper using Microsoft Excel Non-Linear Solver) of the firm's stock price, stock price volatility, and leverage ratio. We investigate how these parameters affect deposit liabilities of the banks and their equity values. The parameters whose value change in the sensitivity analysis are the equity volatility, equity value (market capitalisation) and liabilities.

5.3.1 Analysing Sensitivity to Changing Equity Volatility

In this section, the equity volatility changes while all other parameters are as estimated and reported in Table 2. As shown in Figure 1 for Bank1, the higher the equity volatility, the greater the Probability-of-Default (PD), as expected and the more the likelihood of failure. The relationship seems to be more linear than the relationship between Equity Volatility and those of Yield-to-Maturity, Implied-Credit-Spread, Trigger-Intensity and CoCoSpread that produced slightly convex curves. In all cases, as the Equity Volatility increases, Yield-to-Maturity, Implied-Credit-Spread, Trigger-Intensity and CoCoSpread also increase. The same outcome was observed for Bank2 and

Bank3 but not shown because of space.

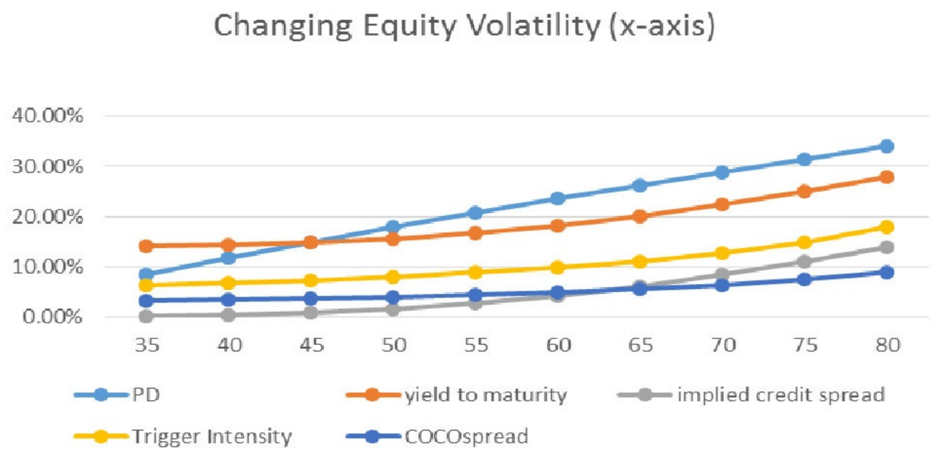

Figure 1: Bank1 Sensitivity Analysis to Equity Volatility

Table 5a also shows the unobervable asset value and asset volatility of Bank1 inferred from the market values using the Merton approach. It can be seen from the Table that the asset value is stable around N273 to N276 billion for equity volatility ranging around 35-80% for Bank1. Table 5b also shows the asset value and asset volatility of Bank3 inferred from the market values using the Merton approach. It can be seen from the Table that the asset value is stable around N428 to N431 billion for equity volatility ranging from 45% to 80% for Bank3.

For Bank1, the asset volatility is also steady around 1-2% for the changing equity volatility. However, as the equity volatility increases, the going-concern condition of the bank continues to be threatened as shown by increasing PD and decreasing DD. That leads to increasing probability of hitting the trigger for CoCo conversion.

Table 5a: Bank1, changing only equity volatility

Equity value (B'N)	61.00000	61.00000	61.00000	61.00000	61.00000	61.00000	61.00000	61.00000	61.00000	61.00000
Equity vol (%)	35.00000	40.00000	45.00000	50.00000	55.00000	60.00000	65.00000	70.00000	75.00000	80.00000
Asset value (B'N)	276.08000	276.06000	276.03000	275.96000	275.83000	275.62000	275.31000	274.87000	274.29000	273.53000
Asset vol (%)	0.07700	0.08900	0.10000	0.11200	0.12400	0.14000	0.15100	0.16500	0.18000	0.19700
DD	1.37900	1.19300	1.04500	0.92100	0.81500	0.72000	0.63500	0.55600	0.48200	0.41200
PD	8.40%	11.64%	14.80%	17.84%	20.76%	23.60%	26.30%	28.90%	31.50%	34.00%
Prob of hitting trigger	76.33%	78.42%	81.11%	84.02%	86.93%	89.70%	92.30%	94.60%	96.60%	98.40%

Table 5b: Bank2, changing only equity volatility

Equity value (B'N)	99.00000	99.00000	99.00000	99.00000	99.00000
Equity vol	0.59000	0.50000	0.45000	0.70000	0.80000
Liabilities (B'N)	383.00000	383.00000	383.00000	383.00000	383.00000
Asset value (B'N)	431.32000	431.77000	431.89000	430.07000	427.95000
Asset vol (%)	0.14000	0.12000	0.10000	0.17000	0.20000
DD	0.78000	0.98000	1.11000	0.59000	0.44000
PD	21.60%	16.40%	13.40%	27.70%	32.90%
Yield to maturity	17.70%	15.50%	14.70%	22.20%	27.80%
Implied credit spread	3.70%	1.50%	0.70%	8.20%	13.80%
Recovery rate	50.00%	50.00%	50.00%	50.00%	50.00%
Prob of hitting trigger	89.20%	84.00%	81.10%	94.60%	98.40%
Trigger Intensity	9.60%	8.00%	7.20%	12.70%	17.90%
CoCo spread	4.80%	4.00%	3.60%	6.30%	9.00%

The same outcome was observed for Bank3 but not shown because of space.

5.3.2 Analysing Sensitivity to Changing Market Capitalization
Tables 6a and 6b show the estimated values of interest when all other parameters are held constant but market capitalization of Bank1, Bank3 and Bank2 (not displayed) banks changes. The table shows that increasing the market capitalization for Bank1 also increases the asset value inferred from the Merton model, asset volatility as well as a rise in the DD and lower PD, corresponding to lower default by the bank. That also resulted in a constant or static COCO spread, probability of hitting the trigger for CoCo conversion and Trigger Intensity. Therefore, increasing equity market capitalization increases the going-concern status of Bank1 and decreases both the yield to maturity and implied credit spread, because the bank is in a better financial

condition that does not support the need for CoCo conversion of bonds to equity.

Table 6a: Bank1 with changing market capitalization

Equity value(B'N)	40.00000	50.00000	70.00000	75.00000	80.00000
Asset value	254.37000	264.29000	284.20000	289.19000	294.18000
Asset vol	0.11000	0.13000	0.17000	0.18000	0.19000
DD	0.19700	0.44000	0.73000	0.79000	0.83000
PD	42%	33%	23%	22%	20%
Yield to maturity	21%	21%	20%	20%	20%
Implied credit spread	7%	7%	6%	6%	6%
Prob of hitting trigger	93%	93%	93%	93%	93%
Trigger Intensity	11%	11%	11%	11%	11%
CoCo spread	6%	6%	6%	6%	6%

Table 6b: Bank3 with changing market capitalization

Equity value (B'N)	70.00000	80.00000	110.00000	150.00000	200.00000
Equity vol	0.59000	0.59000	0.59000	0.59000	0.59000
Liabilities(B'N)	383.00000	383.00000	383.00000	383.00000	383.00000
Asset value (B'N)	402.39000	412.36000	442.31000	482.30000	532.33000
Asset vol	0.11000	0.12000	0.15000	0.19000	0.22000
DD	0.41000	0.57000	0.88000	1.14000	1.35000
PD	34.01%	28.56%	18.90%	12.74%	8.82%
Yield to maturity	18.25%	18.06%	17.56%	17.00%	16.44%
Implied credit spread	4.25%	4.06%	3.56%	3.00%	2.44%
Prob of hitting trigger	89.16%	89.16%	89.16%	89.16%	89.16%
Trigger Intensity	9.65%	9.65%	9.65%	9.65%	9.65%
CoCo spread	4.82%	4.82%	4.82%	4.82%	4.82%

The same outcome was observed for Bank2 but not shown because of space.

5.3.3 Analysing Sensitivity to Changing Liabilities

Table 7 shows the estimated values of interest when all parameters are held constant except the banks' Liabilities that change. The table shows that increasing the Liabilities of Bank1 (Table 7a) and Bank3 (7b) also increases the asset value inferred from the Merton model, decreases their asset volatilities and DDs but raises the banks' PD, corresponding to higher default by the banks.

Table 7a: Bank1 with changing Liabilities

Liabilities	180.00000	200.00000	225.00000	270.00000	300.00000
Asset Value (B'N)	216.82400	234.14900	255.81300	294.82700	320.84700
Asset Vol (%)	0.19300	0.17900	0.16500	0.14400	0.13200
DD	0.86900	0.79100	0.69800	0.54100	0.44200
PD	19.24%	21.46%	24.26%	29.42%	32.93%
Yield to maturity	19.67%	19.95%	20.24%	20.66%	20.89%
Implied credit spread	5.67%	5.95%	6.24%	6.66%	6.89%
Prob of hitting trigger	92.74%	92.74%	92.74%	92.74%	92.74%
Trigger Intensity	11.39%	11.39%	11.39%	11.39%	11.39%
CoCo spread	5.70%	5.70%	5.70%	5.70%	5.70%

Table 7b: Bank3 with changing Liabilities

Equity value (B'N)	99.00000	99.00000	99.00000	99.00000	99.00000
Equity vol	0.59000	0.59000	0.59000	0.59000	0.59000
Liabilities (B'N)	250.00000	300.00000	350.00000	410.00000	450.00000
Asset value (B'N)	315.90000	359.28000	402.68000	454.76000	489.49000
Asset vol (%)	0.19000	0.17000	0.15000	0.13000	0.12000
DD	1.15000	1.00000	0.87000	0.72000	0.62000
PD	12.56%	15.83%	19.27%	23.64%	26.69%
Yield to maturity	16.97%	17.31%	17.58%	17.84%	17.99%
Implied credit spread	2.97%	3.31%	3.58%	3.84%	3.99%
Prob of hitting trigger	89.16%	89.16%	89.16%	89.16%	89.16%
Trigger Intensity	9.65%	9.65%	9.65%	9.65%	9.65%
CoCo spread	4.82%	4.82%	4.82%	4.82%	4.82%

That also led to a constant or static COCO spread, probability of hitting the trigger for CoCo conversion and Trigger Intensity. Therefore, increasing Liabilities reduces the going-concern status of the three banks (Bank2 analysis, though not displayed, but still presented same findings) and increases both the yields to maturity and implied credit spreads, because the banks are not in good financial conditions and as the liability increases, more support is gathered for CoCo conversion of bonds to equity. The same outcome was observed for Bank2 but not shown because of space.

6.0 Conclusion and Policy Implications

The paper described the features, characteristics and application of CoCos for bank recapitalisation. CoCos, like bail-in bonds recapitalisation, have the same objective of making bondholders contribute to the cost of resolving a failing/failed bank. It should be noted that there is no universally-accepted way of designing CoCos. Rather, a decision should always be taken based on a particular bank's condition.

This paper also analysed the three CoCo pricing categories: credit derivatives or reduced form, equity derivative approach and structural approach. The presented pricing approaches are useful for valuing CoCos while their assessment should broaden and provide insight to investors, bankers and regulators seeking to use them for different objectives. The paper then applied the three pricing frameworks to the CoCo resolution of three Nigerian banks that were initially resolved using the bridge-bank mechanism that relied on very costly bail-out using public funds. It was found that similar to the result obtained from the structural model, the credit derivatives approach reported the highest credit spread to be by the CoCo of Bank1, followed by CoCo of Bank3 and Bank2 with the least but non-zero value. Equity derivatives approach however, priced the highest spread and yield to CoCo of Bank3 followed by Bank1 with Bank2 also, having the lowest non-zero spread. The study showed that the credit derivatives and equity derivatives approaches as well as the structural model of Merton all produced different values for the parameters required to issue CoCo bonds. That can be explained because of the differences in the assumptions and other mechanics of the models but the three CoCo pricing frameworks arguably explain the economics of CoCos appropriately.

Out of the three CoCo pricing approaches, the structural Merton model was selected as the most appropriate for structuring CoCos. That is because, this approach reported the least pricing errors by other researchers and builds asset values of the banks from publicly-available quoted stock prices as well as deposit components of bank's balance sheet information. Furthermore, the Distance-to-Default, a measure calculated from Merton's model, has been used to monitor risks of financial institutions by international organizations and is an important forward-looking indicator that can provide early signs of bank fragility.

However, the study is limited to zero-coupon bonds and analysis of issuing coupon bearing CoCo bonds should be explored using the models implemented in this study as well as several others. Also, the models used did not consider jumps, stochastic risk free and simulation-based CoCo pricing techniques that can be considered for future work.

Nigerian banks, especially domestic systemically important ones, should be encouraged to issue CoCo bonds as a way of bank recapitalisation if the scenario arises. The regulators should establish and ensure implementation of appropriate Know-Your-Customer (KYC) by all CoCo investors in Nigeria. Beyond KYC, the relevant financial sector regulators should be heavily involved in the design of CoCos with financial stability objectives and possibly incorporate some measure of systemic risk as the trigger for conversion to equity.

References

Albul, B., Jaffee, D.M. and Tchistyi, A. (2010). Contingent Convertible Bonds and Capital Structure Decisions, University of California, Berkeley, Working Paper.

Alessandri, P. and Haldane, A. G. (2011). Banking on the State. In The International Financial Crisis: Have the Rules of Finance Changed? 169-195. Presented at the Federal Reserve Bank of Chicago Twelfth Annual International Banking Conference.

Allen, L., Boudoukh, J. and Saunders, A. (2009), Understanding market, credit, and operational risk: the value at risk approach. John Wiley & Sons.

Avdjiev, S., Bogdanova, B., Bolton, P., Jiang, W. and Kartasheva, A. (2017). CoCo issuance and bank fragility (No. w23999). National Bureau of Economic Research.

Avdjiev, S., Kartasheva, A. and Bogdanova, B. (2013). CoCos: a primer. BIS Quarterly Review, 43-56.

Bloomberg (2009). How to price an auto-callable note with OVSN. Bloomberg Technical Report November 2009.

Boermans, M., Petrescu, S. and Vlahu , R. (2014), "The future for CoCos ", available from VoxEU.org, 17 November 2014.

Boermans, M. A., and van Wijnbergen, S. (2018). Contingent convertible bonds: Who invests in European CoCos? *Applied Economics Letters*, 25(4), 234-238.

Bundesbank, Deutsche (2018), Contingent convertible bonds: design, regulation, usefulness, Monthly Report, 53.

Calomiris, C.W. and Herring, R. J. (2011) Why and How to Design a Contingent Convertible Debt Requirement. Working paper available from SSRN: http://ssrn.com/abstract=1815406.

Central Bank of Nigeria, CBN (2011). Supervisory Intervention Framework for the Nigerian Banking Industry. Banking Supervision Department and Financial Policy & Regulation Department, CBN.

Chen, N., Glasserman, P., Nouri, B. and Pelger, M. (2013). CoCos, Bail-In, and Tail Risk. Office of Financial Research Working Paper No. 0004.

De Spiegeleer, J.. and Schoutens, W. (2011a). Pricing contingent convertibles: A derivatives approach. https://ssrn.com/abstract=1795092.

De Spiegeleer, J.. and Schoutens, W. (2011b). Steering a bank around a death spiral: Multiple trigger CoCos. https://ssrn.com/abstract=1976985.

De Spiegeleer, J., Schoutens, W. and Van Hulle, C. (2014). The handbook of hybrid securities: convertible bonds, coco bonds, and bail-in. John Wiley & Sons.

Duffie, D. and Singleton, K. J. (2003). Credit risk: pricing, measurement, and management. Princeton University Press.

Erismann, M. (2015). Pricing contingent convertible capital-a theoretical and empirical analysis of selected pricing models . Doctor of Philosophy Thesis, University of St. Gallen, School of Management, Economics, Law, Social Sciences and International Affairs.

European Banking Authority (2011). Recommendation on the Creation and Supervisory Oversight of Temporary Capital Buffers to Restore Market Confidence. http://www.eba.europa.eu/

Flannery, M. J. (2002) No Pain, No Gain? Effecting Market Discipline Via 'Reverse Convertible Debentures'. Working paper available from http://dx.doi.org/10.2139/ssrn.352762.

Flannery, M. J. (2009) Stabilizing Large Financial Institutions with Contingent Capital Certificates. Working paper available from SSRN: http://ssrn.com/abstract=1485689 (accessed August 2017).

Flannery, M. J. (2014). Contingent capital instruments for large financial institutions: A review of the literature. *Annu. Rev. Financ. Econ.*, 6(1), 225-240.

Glasserman, P. and Nouri, B. (2012). Contingent capital with a capital-ratio trigger. Management Science, 58(10), 1816-1833.

Independent Commission on Banking (2011) Independent Commission on Banking of U.K. Final Report. Recommendations.

Katata, K. and Nwaigwe, O. (2016). Bail-In as an alternative failure resolution mechanism in Nigeria. NDIC Quarterly, September 2016 Edition.

Krishnan, M., and Jacoby, P. (2012). Bail-in Capital: The New Box. World Academy of Science, Engineering and Technology, International *Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, 6(1), 88-92.

Liebenberg, F.J.N., Van Vuuren, G.W. & Heymans, A., (2018), 'Exploring contingent convertible bond alternatives for African banks', *South African Journal of Economic and Management Sciences* 21(1), a2286. https://doi.org/10.4102/sajems.v21i1.2286

McDonald, R. (2010) Contingent Capital with a Dual Price Trigger, working paper, Finance Department, Kellogg School of Management, Northwestern University.

Merton, R. C. (1974). On the pricing of corporate debt: The risk structure of interest rates. *The Journal of finance*, 29(2), 449-470.

Nigeria Deposit Insurance Corporation, NDIC, (2009), 20 Years of Deposit Insurance in Nigeria, Research Department, Nigeria Deposit Insurance Corporation.

Nigeria Deposit Insurance Corporation, NDIC (2013), Bridge Bank as a Failure Resolution Option in Nigeria, NDIC.

Nordal, K. B. and Stefano, N. (2014). Contingent convertible bonds (cocos) issued by european banks, Norges Bank Staff Memos, NR. 19.

Pazarbasioglu, C., Zhou, M. J. P., Le Leslé, V., & Moore, M. (2011). Contingent capital: economic rationale and design features. International Monetary Fund.

Pennacchi, G. (2010) A Structural Model of Contingent Bank Capital. Federal Reserve Bank of Cleveland, Working Paper No. 10-04.

Rüdlinger, M. (2015), Contingent Convertible Bonds: An Empirical Analysis of Drivers and Announcement Effect, PhD Thesis, University of St. Gallen, School of Management, Economics, Law, Social Sciences and International Affairs,

Sanusi, S. L. (2010). The Nigerian banking industry – what went wrong and the way forward Text of the Convocation Lecture by Governor of the Central Bank of Nigeria, to mark the Annual Convocation Ceremony of Bayero University, Kano.

Sanusi, S. L. (2012a). Banking Reform and its Impact on the Nigerian Economy. Being a Lecture delivered at the University of Warwick's Economic Summit, UK.

Sanusi, S. L. (2012b). The Global Financial Crisis and the Nigerian Economy: The Central Bank of Nigeria's Response. Being a Lecture delivered at the Sir Patrick Gillam Annual Lecture, Sheikh Zayed Theatre, New Academic Building, London School of Economics and Political Science (LSE), London, United Kingdom.

Skinner, F. S. and Ioannides, Mi. (2011), Contingent Capital Securities: Problems and Solutions. Derivative Securities Pricing and Modelling, J. Batten and N. Wagner, eds., Emerald Press, 2011.

Stamicar, R. (2016). CoCo Risk: Practical Approaches to Measuring Risk. Research Paper, (72). Available from https://www.institutionalinvestor.com (accessed May 2019).

Sundaresan, S. and Wang, Z. (2011). On the Design of Contingent Capital with Market Trigger. Federal Reserve Bank of New York, Staff Report no. 448.

Swiss Commission of Experts (2010). "Too big to fail" issues. Technical report, Swiss Commission of Experts.

Wilkens, S. and Bethke, N. (2014). Contingent Convertible ('CoCo') Bonds: A First Empirical Assessment of Selected Pricing Models. *Financial Analysts Journal*, Vol. 70, No. 2.