Jurnal Ekonomi Malaysia 46(2) 2012 101 - 114

Momentum and Nonlinear Price Discovery in Sovereign Credit Risk and Equity Markets of the Organization of Islamic Cooperation (OIC) Countries

(Momentum dan Penemuan Harga Tidak Liner pada Risiko Kredit Tertinggi dan Pasaran Ekuiti Negara-negara Pertubuhan Kerjasama Islam (OIC))

Geoffrey Ngene
Stetson School of Business and Economics
Mercer University

M. Kabir Hassan
Department of Economics and Finance
University of New Orleans

ABSTRACT

This paper hypothesized that there is a differential response by agents to changes in sovereign credit risk in both calm (low default risk) and turbulent (high default risk) markets. These market conditions create two different states of the world or regimes. The two model regimes have been made using threshold cointegration and vector error correction model in three possible pairs of sovereign CDS, bond and equity markets for four emerging markets. Moreover, evidence of momentum in cointegration relationships in 75% of the time. Positive and negative divergences adjust to equilibrium relationship and value (threshold) at different speeds and magnitudes depending on the regime. Moreover, short-term nonlinear adjustment process is found in 50% of possible asymmetries. The informativeness of each asset in a pair is nonlinear and regime dependent in 14/24 possible price discovery processes. Therefore, dynamic interaction among assets held in a portfolio shift with regime change. Investors, in making decisions regarding portfolio rebalancing and hedging against downside risk need to identify when regimes change to make informed decisions while policy makers need to identify the threshold below or above which policy intervention in the market becomes necessary. Linear modeling may provide mis-specified and biased results as indicated by comparative results of linear and nonlinear modeling.

Keywords: Price discovery; financial integration; CDS; sovereign bonds; equity index and credit risk JEL

ABSTRAK

Kertas ini menghipotesiskan bahawa terdapat perbezaan tindak balas daripada ejen-ejen kepada perubahan pada risiko kredit tertinggi kepada kedua pasaran tenang (risiko lalai rendah) dan tidak tenang (risiko lalai tinggi). Pasaran ini mewujudkan dua keadaan yang berlainan dunia atau rejim. Kedua-dua rejim model telah dibuat menggunakan kointegrasi ambang dan vektor pembetulan ralat model dalam tiga pasang mungkin CDS tertinggi, pasaran bon dan ekuiti untuk empat pasaran baru. Selain daripada itu, bukti momentum dalam hubungan kointegerasi adalah 75% daripada masa. Perbezaan positif dan negatif menyesuaikan diri kepada hubungan keseimbangan dan nilai (ambang) pada kadar dan magnitud yang berbeza bergantung kepada rejim yang wujud. Tambahan, proses pelasaran jangka masa pendek tidak linear terdapat pada 50% asimetri kemungkinan. Kelebihan maklumat setiap aset-aset berpasangan ini adalah tidak linear dan bergantung kepada dan rejim bergantung pada 14/24 proses penenuam kemungkinan harga. Oleh yang demikian, perhubungan dinamik antara aset-aset di dalam sebuah portfolio berubah mengikut perubahan rejim. Pelabur, dalam membuat keputusan mengenai pengimbangan semula portfolio dan melindung nilai terhadap risiko penurunan perlu untuk mengenal pasti apabila rejim bertukar untuk membuat keputusan terkini, manakala pembuat dasar perlu mengenal pasti ambang di bawah atau di atas mana campur tangan dasar di pasaran menjadi perlu. Model linear boleh menyediakan salah dinyatakan dan keputusan berat sebelah seperti yang ditunjukkan oleh keputusan perbandingan model linear dan tak linear.

Kata kunci: Penemuan harga; integrasi kewangan; CDS; kredit tertinggi; indeks ekuiti dan risiko kredit

INTRODUCTION

Extant literature unreservedly surmises that the price discovery mechanisms are both constant and continuous under linear modeling. This is only realistic if financial markets are dominated by homogeneous agents. However, a large body of finance literature lucidly document that financial markets are dominated by heterogeneous agents. Hommes and Wagener (2009), using the seminal works of Simon (1991) and Rubinstein (1998), argue that financial markets are complex adaptive systems, dominated by incessantly interacting heterogeneous agents with "bounded rationality". The heterogeneous agents thus have limited information, cognitive abilities and finite time availability for decision-making. Against this background, rationality of agents is limited and the use of rules of thumb is highly prevalent. Therefore, financial markets become nonlinear systems. According to Mankiw and Miron (1986), the mere existence of 'calm' and 'volatile' market conditions creates time varying states of the world or regimes. These regimes are testaments of the uncertain environment under which agents make decisions based on the new information they receive and accordingly adjust their expectations. For example: Lee, Fang and Lin (2007) argue that crises episodes such Asian crisis of 1997 and sub-prime mortgage crisis of 2007/2008 triggered negative impact on both investors' wealth and domestic, regional or global economies. This became the foundation of acute convergence of investors' sentiments and led to asymmetric transmission of price variance among CDS, stocks and bonds across domestic and international markets. In the 'volatile' regime, policy makers aggressively intervene in the market and real economy to level the fluctuations and alleviate investors' fear and overreaction while investor takes aggressive actions to rebalance their portfolio and hedge against or minimize further wealth loss.

The pricing of sovereign credit risk using CDS premium, bond yields and equity prices occurs under uncertain markets conditions where institutional investors in the over-the-counter (OTC) market toggle among diverse trading strategies. These strategies generate nonlinear short and long-term dynamic interactions among asset classes, price informativeness and price discovery processes. For any pair of assets, the sign and magnitudes of speed of adjustment to new information also become nonlinear. Acharya and Johnson (2007) shows that CDS market asymmetrically and exclusively reveal the "bad news" or adverse shocks associated with credit deterioration. Chan-Lau and Kim (2004), using linear modeling, did not find any equilibrium price relationship between sovereign bond, CDS markets and the equity markets for most of the sovereigns they covered. One of the possible explanations they give for their findings is nonlinearities in time series data due to high volatility of security prices and returns that characterize emerging markets (Bekaert and Harvey 2002).

Delatte et al. (2010) find that in a single country, price discovery pecking order may be reversed above a definite threshold of spread depending on market conditions. In fact, the market in which price discovery occurs may be dependent upon financial, economic, liquidity and other factors not captured by the linearity relationship. Gomez (2003) finds that looking only at the relationship between credit derivatives and cash bond markets is insufficient, and suggests including equity markets as well in the analysis. Indeed, Cremers (2004) and Zhang et al. (2005) find similar evidence and strongly argue for the case of connecting the prices of CDS, bond and equity markets in pricing credit risk.

Motivated by these findings, the bounded rationality that investor's face, the prodding by various authors and dearth of studies in nonlinear pricing of credit risk, we seek to address the following questions: Are sovereign CDS spreads, bond spreads and equity prices characterized by nonlinearities including non-linear unit root behavior? Does a threshold exist below or above which cointegration, price discovery and informativeness of each asset, short term and long term adjustment process will change? How do these dynamics compare with linear modeling? Is there momentum in some pairs of the three markets and how does this momentum, if it exists, affect dynamic interaction among the three markets? We verify these arguments by testing for nonlinearities in pricing of sovereign credit risk, price discovery process, and short and long-run adjustment to equilibrium relationships in pairs of sovereign CDS premium, bond spreads and equity prices.

There has been no empirical study focusing on nonlinear pricing of credit risk of organization of Islamic Cooperation (OIC) countries. In this study, we focus on four OIC countries namely Indonesia, Malaysia, Tunisia and Turkey. These countries, tagged as emerging markets, are not only geographically dispersed across three continents but they also differ in various fronts. First, each country has unique time varying level of default risk as priced by credit default swaps (CDS), bond spreads and equity prices. Second, the countries have different levels of economic and financial development, political stability, financial architecture and degree of integration with global economy and financial market. These factors influence the pricing of default risk by investors. Third, cultural factors play a role in trading of securities. Chui, Titman and Wei (2010) find that the momentum effect in the stock market is stronger in countries with stronger degree of individualism, implying that cultural factors affect trading behavior. The four OIC countries have different cultural heritage and thus trading behavior especially in equity markets. Fourth, the levels of market frictions, which may deter attainment of equilibrium relationship between cointegrated pair of securities, vary across time and countries. Transaction costs, taxes, regulations and liquidity of equity markets are unique to each country hence the need to analyze them individually. Fifth, sovereign CDS premium, bond yield and equity prices are influenced by the fiscal policies and budget deficits of unique to each country.

We find evidence of momentum in cointegration relationships in 9/12 possible contegrations. In 12/12 combinations, we find that that positive and negative divergences adjust to equilibrium relationship at different speeds and magnitudes depending on the regime. Moreover, asymmetric short-run adjustment process is found in 13/24 possible asymmetries. The informativeness of each asset in a pair is asymmetric and regime dependent in 14/24 possible asymmetric price discovery processes while the speed of adjustment to new information change as regime change. Therefore, dynamic interaction among assets held in a portfolio shift with regime alteration. Linear modeling may provide mis-specified and biased results as indicated by comparative contradictory results of linear and nonlinear modeling. The findings have important implications for asset allocation and portfolio rebalancing decisions by investors, policy intervention in financial markets, risk management and regime specific short and/or long term dynamic interactions among assets held in a portfolio as well as nonlinear speed of adjustment to new information.

We contribute to the existing literature in a number of ways. First, this is the first study, to the best of our knowledge, to investigate nonlinear co-integration and short term and long run dynamic interaction of sovereign CDS premium, bond spreads and equity using a large data set of seventeen emerging markets. This is important because linear modeling ignores discontinuities associated with regime change over time. Two, we assess the effects of momentum (intensified reaction in one regime relative to substitute regime or direction) in cointegration and price discovery process. This accounts for asymmetry in the relationships and the role of trading adjustment costs among arbitrageurs. Three, in assessing price discovery among the three markets, we employ a unified econometric model (Threshold error correction model) and compare it with linear models to uncover contradictions and similarities. For example: Is linear price discovery more consistent with lower regime or upper regime? The sign of error correction term in different regimes can help identify which market can trigger momentum and arbitrage opportunities as regime shifts occur and presence of any price bubbles. Lastly, we implicitly incorporate 2007-8 financial crises since this period is captured as part of the "volatile" regime during which momentum is likely to occur.

The rest of the paper is organized as follows. Section II reviews the literature and develops testable hypotheses. Section III details econometric methodology. Section IV explains empirical results and findings and section V shall summarize and conclude

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Academic literature and study on the relationship among credit derivatives, bond, and equity markets is very small (Chan-Lau and Kim 2004). Linden (2010), argue that the existing literature on the interaction of CDS and bond markets focuses mainly on the pricing of risk and the role of both markets in price discovery. Furthermore, the vast majority of the research conducted is based on the linear modeling of bond markets, CDS markets and interaction between stock options and the underlying stocks from corporate perspective.[1] Although studies by Longstaff, Mital and Neiss (2005), Norden and Weber (2004), Forte and Peña (2008), Pan and Singleton (2008), Norden and Weber (2009) and Meng, Gwilym, and Varas (2009) span the three markets, only Chan-Lau and Kim (2004) and Pan and Singleton (2008) have focused on sovereign CDS, bonds and equity markets using Merton's (1974) theory. This theory can be extended to sovereign CDS premium, bond spreads and equity markets.[2] The study by Pan and Singleton (2008) covered only three emerging markets (Turkey, South Korea and Mexico).

THEORETICAL FOUNDATION: RELATIONSHIP BETWEEN BOND AND EQUITY MARKETS

The option pricing theory developed by Merton (1974) is the fulcrum around which the relationship between bond and equity prices revolves. According to the theory, equity is equivalent to a call option whenever a limited liability firm issues a bond or is financed by debt. By issuing a bond (assumed a zero coupon bond) and using the assets of the collateral, equity holders have theoretically 'sold' the firm to creditors or bondholders. Equity holders thus hold a call option to buy back and own the assets only after paying back the face value (strike price) of debt to creditors. The option life is equal to maturity period of the bond. If we define C as value of call option, S as market value of assets at maturity and F as face value (Strike price) of a zero coupon bond, then, at maturity, $C=\max(S-F, 0)$

If $S-F>0$, the firm's assets are worth more than the debt's face value and the call option is "in-the-money". Equity holders will exercise it by paying off the debt and 'buy back' the assets otherwise, equity is worthless, and the call option is "out-of-the-money." In Merton's capital structure framework, the face value of bond constitute a lower threshold which the value of firm's assets cannot breach. If this barrier is breached ($S<F$), the firm is likely to default on its debt. S-F is ideally a distance to default. As this distance is reduced, the leverage of the firm increases, credit risk rises and bond yield increases (to reflect higher credit risk) and value of equity declines further. Merton's (1974) structural model is used to estimate the probability of default (PD) of a firm and risk premium (yield of a risky bond less yield of a risk-free bond of same maturity)

When PD or credit risk is high (as characterized by high leverage and below investment-grade credit ratings),

[1]See for example Norden, Lars and M. Weber 2004, Hull, Predescu, and White (2004), Blanco, Brennan, and Marsh (2005), Berndt and Ostrovnaya (2007), Forte and Lovreta (2008), Forte (2008), Ammer and Fang (2008), Norden and Weber (2009).

[2]See Chan-Lau and Kim (2004) paper which illustrates how corporate credit risk modeling can be extended to sovereign bonds and credit risk.

there is a strong positive correlation between equity and bond prices since both prices will plummet to incorporate higher credit risk. Zhu (2006) and Realdon (2008) finds that the firm's stock price contain important information regarding default intensity especially when the default risk is high (call option is out-of- the-money) and the markets are distressed. However, equity prices are less useful conduits of conveying default risk of the firm when default risk is low. This is because equity prices will be driven primarily by firm's fundamentals and not default risk.

The co-movement of stock and bond returns has been observed in a variety of other models by French and Roll (1986), Fama and French (1989, 1996), Asquith, Gertner, and Sharfstein (1994), Opler and Titman (1994), Denis and Denis (1995), Fleming and Remolona (1997), Campbell and Taksler (2003), and Vassalou and Xing (2004)). The overall evidence shows that the relationship between equity and bond returns vary over time, particularly under exogenous influences.

Ho_1: There exists time varying and nonlinear cointegration relationship between bond yield (spreads) and equity prices. The influence of exogenous factors creates momentum in one regime relative to alternative regime.

RELATIONSHIP BETWEEN CDS AND EQUITY AND CDS AND BONDS

Merton theory can be extended to explain the relationship between CDS spreads and equity prices. When credit risk is a key concern to bondholders, investors will dump equity which will precipitate a decline in stock prices. There will also be intensified demand for CDS of the firm to insure against potential default. This will lead to increase in CDS spreads. We can thus again infer that relationship between CDS spreads and equity prices has to be negative. Yu (2006) notes that the premise of capital structure arbitrage is that the theoretical relation between the CDS spread and the equity price would reign in the long run. The attainment of the long run relation implies that CDS position can cushion the loss from the equity position and vice versa. This will eliminate the arbitrage opportunities and make the CDS and equity markets more integrated and efficient in pricing default risk.

Hull and White (2000, 2001) and Duffie (1999) lucidly explain that CDS premium makes the bond default risk free. If *y* is the yield to maturity of a bond and *CDS* premium is the cost of insurance, the riskless (rf) net percent return on the bond is *y –CDS*. If arbitrage opportunities do not exist, y *–CDS =rf. y –rf* is the zero-coupon par-floating bond spread (BYS) theoretically equal to CDS if markets are frictionless and payment of the CDS spread discontinues on occurrence of a credit events.

There are two important inferences that we can make from Merton's theory. First, there is negative correlation between CDS premium and equity prices. Second, CDS premium, bond spreads and equity prices adjust simultaneously whenever new information on credit risk is released in the market. Empirical evidence by Hull et al. (2004), Blanco et al (2005) and Longstaff et al. (2005) show that corporate CDS in U.S and Europe adjusts to or incorporate new credit risk information well before bond prices. Therefore, corporate CDS market leads in price discovery process. Acharya and Johnson (2007) conclude that negative credit news lead to shocks in equity market.

Can we employ Merton's theory and argument to emerging markets or countries' (ECs) sovereign bonds, equity and CDS especially given that a sovereign issuer may choose to default even when it is technically solvent? A Merton-type theoretical justification can be explained as follows: A country with a higher default risk will experience a decline in its stock market performance either because economic and financial fundamentals are deteriorating or because domestic and international investors are demanding higher risk premium or both. Thus, the price of the country's stock market would fall. The cost of buying insurance (CDS spread) against country's default risk will increase. As credit risk increases, the demand for insurance against potential default by the sovereign increases. This exerts a further pressure on equity prices since sellers of credit derivatives will be shorting either bonds or equity mitigates their exposure from potential losses.

Forte and Lovreta (2008) argue that credit risk in the stock market is implicit in nature since CDS and stock markets have stark differences in several fronts such as organization, participants (Longstaff et al. 2005), investor base, risk preferences, reactions to news, liquidity, and stage of development. For example: Sovereign bond market is dominated by less diverse institutional investors who tend to buy and hold bonds, not tending to react to developments in other markets. These differences among CDS, bond and stock markets are likely to cause short-term deviations from the long-term relationship. I hypothesize that the short term deviation and long term relationship is regime specific and nonlinear.

Ho_2: There exist a nonlinear short term and long-term relationship between sovereign CDS premium and bond spreads on one hand and sovereign CDS premium and equity markets on another.

PRICE DISCOVERY AND INFORMATIVENESS OF SECURITY PRICES

Stein (1987) argues that the entry of new investors potentially lowers the informativeness of bond prices. This lowers the ability of pre-existing investors to conjecture asset value. This could trigger price instability and reduction in welfare benefits. There is limited research on the price discovery dynamics of the sovereign CDS, bonds and equity under different market conditions. Anecdotal evidence[3] shows that CDS has higher default risk anticipatory power than both stock and equity market. Zhang (2008) finds that Argentina's CDS could predict credit events in the country well before the rating agencies since credit rating often lags credit events. Chan-Lau and Kim (2004) perform cointegration and causality tests and price discovery analysis for the stock market, sovereign bond market, and the CDS market. They find no equilibrium relationship between sovereign bond and CDS markets while price discovery and causality tests yielded mixed results. In particular, equity markets play insignificant role in price discovery while sovereign CDS leads in price discovery in most of the sovereigns in the study.

Aktug, Geraldo and Bae(2008) study thirty sovereigns and find mixed evidence in which sovereign bond markets lead CDS markets in 48% of the time but lag CDS spreads in 22% of the time). Fung et al (2008) investigates the market-wide relations between the U.S. equity and CDS markets and find that there is significant bidirectional information and volatility feedback between equity market and the high-yield CDS (high credit risk). However, the equity market leads the investment-grade CDS (low credit risk) in price discovery.

Chan, Fung and Zhang (2008) find that price discovery takes place primarily in the CDS market in six out of seven emerging markets. They attribute this to shallow and underdeveloped stock market while the counterpart CDS market has fewer restrictions, broader investor base, and greater information advantage. Ammer and Cai (2008) investigate price discovery between sovereign bonds and CDS. They find that in four out of the nine sovereigns studied, CDS spreads lead bond spreads in price discovery. They attribute the significant short run deviation between the two markets to relative liquidity and contract specifications of each market particularly the cheapest-to-deliver (CTD) option which encumbers CDS liquidity for riskier sovereigns.

Ho_3: *The price discovery and informativeness of each security in a given pair is regime dependent. Moreover, the speed of adjustment to new information changes with regime variation.*

The mixed findings by individual authors and among the authors confirm that there is inconclusive evidence as to which market (Sovereign CDS, bond or stock market) leads in price discovery. Past evidence is based on linear modeling. We employ nonlinear modeling and compare the results of price discovery and speed of adjustment new information with linear modeling to uncover consistencies and contradictions if any.

ECONOMETRIC METHODOLOGY AND EMPIRICAL RESULTS

We use the daily closing prices of sovereign CDS spreads, bond spreads and national stock indices of each sovereign. Each country has different starting date but data ends on November 2nd 2009. The data is provided by Datastream and JP Morgan Chase. The two sources are the main providers for of credit derivatives research data. In the global credit derivative trading, the 5-year sovereign CDS contracts are among the most liquid and most actively traded securities. Anecdotal evidence from data provided by Depository Trust and Clearing Corporation (DTCC) shows that the top six reference names are EMs sovereign CDS by gross notional value. In relation to sovereign bond spreads, we use emerging market bond index (EMBI) spreads for each sovereign entity. The index includes 5-year U.S. dollar denominated debt instruments issued by sovereign and quasi-sovereign entities, with a minimum current face value outstanding of US$500 million. The study covers four OIC emerging markets namely Indonesia, Malaysia, Turkey and Tunisia. Table 1 provides the summary statistics of sovereign CDS premium, bond spreads and equity.

The high volatility (standard deviation of returns) could be a result of thin trading and low liquidity, which characterize security returns in emerging markets (Bakeart and Harvey 2002). These may be one of the causes of nonlinearities in the data.

The shape of distribution as epitomized by skewness and kurtosis is consistent with stylized facts of financial series returns. There is asymmetrical distribution of returns in all three markets of each country since skewness is positive. All the series exhibit leptokurtic (fat tail) distribution (Black, 1976) since Kurtosis is greater or less than 3 in all cases. Apart from Malaysia, equity has the lowest fat tail distribution in all other countries.

The asymmetry in return distribution is also supported by Jacque-Berra statistic which tests the null of normal distribution. The null is decisively rejected due to high statistical significance of JB statistic (non-normal distribution). CDS premium and bond spreads exhibit positive correlation which is as high as 92.8% for Turkey and as low as 51.9% for Indonesia. This is justified since both CDS premium and bond spreads price the same credit risk. As postulated by Merton (1974) and Campbell and

[3]For example, some weeks before GM's debt was downgraded to junk bond on may 5, 2005, the CDS market had anticipate the deterioration in credit quality of GM. Zhang (2008) also find evidence that CDS market anticipated default by Argentina.

Again, according to *The Wall Street Journal*,

"Trading in Harrah's Contracts Surges Before LBO Disclosue," Oct. 4, 2006, Harrah experienced a dramatic spike in the CDS contracts well before the news of leveraged-buyout (LBO) were divulged to the public. However, the stock market lagged the CDS market in incorporating the LBO news.

TABLE 1. Descriptive Statistics

Country	Mean	Correlation Bond	CDS	Std. Dev.	Skew	Kurtosis	JB P-value	Obs
Indonesia								
Bond	107.858	1.000		1.156	12.779	183.487	0.000	1240
CDS	137.923	0.519	1.000	0.083	2.716	32.981	0.000	1240
Equity	416.617	-0.199	-0.277	0.022	-0.031	9.257	0.000	1240
Malaysia								
Bond	140.956	1.000		0.709	-26.925	1057.410	0.000	1938
CDS	76.877	0.609	1.000	0.133	6.931	80.876	0.000	1938
Equity	249.449	-0.606	-0.261	0.005	-0.264	13.631	0.000	1938
Turkey								
Bond	408.622	1.000		0.004	-1.850	34.617	0.000	1938
CDS	393.098	0.928	1.000	0.045	1.178	14.681	0.000	1938
Equity	352.753	-0.870	-0.792	0.010	-0.501	11.660	0.000	1938
Tunisia								
Bond	124.606	1.000		0.419	-8.426	442.366	0.000	1784
CDS	97.800	0.585	1.000	0.036	1.100	9.934	0.000	1784
Equity	2101.692	-0.355	-0.400	0.028	0.033	7.487	0.000	1784

Note: This table summarizes descriptive statistics touching on measures of central tendency (Mean), measure of dispersions (Standard deviation), measures of distribution shape (skew and Kurtosis), measure of normal distribution (Jacque-Berra, JB) and measure of association (Correlation). The mean and correlation are computed using level data (CDS, Bond spread and equity indices) while Standard deviation, skew, kurtosis and JB are computed using continuous returns, $R_t = ln\ (P_{t+1}/P_t)$.The correlations between two assets are matched with the asset in the first column. Obs is the number of observations

Taksler (2003), bond yield (spreads) and equity prices on one hand and CDS premium and equity on the other have negative correlation to imply that as credit risk increases, CDS premium and bond yields (spreads) increases and equity prices decline.

NONLINEAR MODELING: NONLINEAR COINTEGRATION AND MOMENTUM

Nonlinear modeling in pricing of sovereign credit risk can be justified on numerous grounds. First, Marshall (1994) argues that linear VECM guarantee permanent attraction effect regardless of the size of deviation from equilibrium relationship of variables. This is premised on the unrealistic assumption that agents make decisions under a single state of the world. Second, investors are usually only concerned with downside risk hence it is expected that cointegration and price informativeness of different assets in the portfolio will significantly differ between regimes that define presence and absence of downside risk. Third, sovereign CDS buyers are less concerned with risk of default when sovereign borrowers have low budget deficits and responsible fiscal policies. However, when budget deficits balloon and governments' credit rating is downgraded, bondholder react by buying more protection. The CDS premium will increase while bonds prices (yield) will tumble (increase). Stock prices will also react to credit risk and will try to price it accordingly. Therefore, non-linear modeling is justified to capture periods of low and high budget deficits.

Fourth, Mankiw and Miron (1986) state that identification of different regimes through threshold modeling is a way of incorporating uncertainty and time-variation in in variables since regimes represent time varying states of the world which investors face and respond to. Lastly, the theory of finance suggests that there is a limit to arbitrage. Trivial deviations from long run equilibrium may not justify arbitrage process to generate profits hence there must be a threshold beyond which arbitrage becomes profitable. This requires definition of regimes of profitable and unprofitable arbitrage opportunities especially in CDS and bond markets

Our modeling proceeds as follows: After computing descriptive statistics, we test for linear and nonlinear unit root behavior, neglected nonlinearities in unit root testing and other nonlinear tests. We then contemporaneouslycompute the threshold or long-run equilibrium value to which any two series converge (attractor) and identify the apposite modeling (TAR and MTAR). Using appropriate modeling, we then investigate nonlinear cointegration. Lastly, we investigate nonlinear price discovery and adjustment process towards equilibrium relationship between any two series.

We test for nonlinearity using a battery of tests. Patterson and Ashley (2000), argue that a single nonlinearity test only detect or (fail to detect) nonlinearity. However, using numerous nonlinearity tests provides prized information about nonlinear structure in the data generating process on a given time series. Table 2 provides summary of these tests. We use Augmented Dickey-Fuller (ADF) to test for linear unit root. The test has a null of unit root in time series. We then use the Kapetanios, Shin and Snell (KSS, 2003) nonlinear unit test using demeaned series (DM) and de-trended series (DT). The null is nonlinear unit root against nonlinear stationary. Failure to reject null may imply that the ADF test has low power in detecting nonlinearities in time series. To confirm this, we run the ADF regression with lags selected using Bayesian Information Criteria (BIC). To each regression, we conduct the Ramsey (1969) regression error specification test (RESET) by adding the squared and cubed values of estimated dependent variable [(RESET (2)]such that

$$\Delta y_t = \beta_1 y_{t-1} + \beta_p \sum_{t=1}^{p} \Delta y_{t-p} + \delta_1 \Delta \hat{y}_t^2 + \delta_2 \Delta \hat{y}_t^3 + \mu_t$$

We test, using the standard F-statistic, the joint significance of δ_1 and δ_2 to identify any neglected nonlinearities. BDS test of Brock, Dechert, Scheinkman and LeBaron (1996) uses Z-statistic to test non-linear dependence in the time series data. We provide results of 2 and 3 (BDS (2) and BDS (3)) embedding dimension with $\varepsilon/\sigma = 0.9$. The null is that time series observations are drawn from an *i.i.d* process and the alternative is non-linear dependence. Tsay(1986) test of nonlinearity tests the null of linear dependence in time series data against quadratic nonlinear dependence in time series data.

The results from Table 2 shows that CDS premium, bond spreads and equity prices are individually integrated of order one, *I(1)*. However, RESET test indicates neglected nonlinearities even in in all series except equity prices of Indonesia and Tunisia and bond spreads of Turkey and Malaysia. The neglected nonlinearities in unit root behavior is confirmed by KSS (2003) nonlinear unit root test and BDS tests. KSS test fails to reject nonlinear non-stationary behavior in all series except Malaysia bond spreads. The BDS test, with exception of Malaysia bond spreads confirms the time series data is not *I.I.D.* Tsay test confirms quadratic nonlinearities in all except Tunisia and Indonesia equity prices and Malaysia bond spreads.

The integration feature of price series and nonlinearities implies that cointegration analysis is not only imperative but we can also emply nonlinear model. To investigate pricing asymmetry, we utilize threshold cointegration test of Enders and Siklos (2001). The test

TABLE 2. Unit root and nonlinearity tests

Country	ADF	F-RESET 2	KSS-DM	KSS-DT	BDS(2)	BDS(3)	Tsay Test	Order
Indonesia								
Bond	-2.484	***41.31	-1.797	-2.016	***18.201	***20.022	***4.746	30
CDS	-1.749	***75.25	-1.911	-2.414	***5.381	***6.634	***18.35	21
Equity	-1.295	1.840	-1.243	-1.249	***7.692	***9.762	1.378	2
Malaysia								
Bond	-2.536	0.268	***-2.9	-2.400	-0.023	-0.031	0.613	3
CDS	-1.470	***38.76	-1.559	-1.644	***11.787	***14.582	***25.65	29
Equity	-2.079	***90.16	-0.804	-1.168	***7.777	***11.714	**7.204	4
Turkey								
Bond	-0.571	1.090	-1.004	-1.299	***18.682	***21.544	**2.651	2
CDS	-1.847	***24.3	-1.023	-1.643	***14.788	***17.064	***8.622	22
Equity	-0.920	***17.78	-1.397	-1.662	***7.655	***9.84	*3.377	1
Tunisia								
Bond	-1.316	***10.43	-2.551	-1.690	***21.814	***22.446	***3.307*	7
CDS	-2.346	***4.99	-1.408	-1.666	***7.807	***8.72	***7.835*	29
Equity	-1.529	1.300	1.387	-0.224	***15.705	***17.027	0.004	1

Note: ADF is the t-statistic of Augmented Dickey-Fuller unit root test. It test the null of unit root. Critical values are -3.433, -2.863 and -2.567 at 1%, 5% and 10% significant levels. KSS in the t-statistic of Kapetanios, Shin and Snell (2003) test using demeaned series (DM) and de-trended series (DT). The non-asymptotically normally distributed critical values for KSS-DM (KSS-DT) are -3.48 (-3.93), -2.93 (3.40) and -2.66 (3.13). F-RESET (2) is the F-statistic of Ramsey (1969) Regression Specification Error Test with 2 additional regressors to test for nonlinearity and misspecifications in ADF unit root regression equations. ***, ** and * represent significance level at 1%, 5% and 10% respectively.

is an extension of Engle and Granger's (1987) procedure to incorporate potential asymmetric adjustment to equilibrium relationships of two cointegrated series. Suppose x and y are price variables which are *I(1),* the cointegrating relationship can be modeled using a simple regression equation as

$$y_t = \beta_0 + \beta_1 x_t + \varepsilon_t \qquad \text{(i)}$$

$e_t = \hat{e}_t$ is the estimated stochastic disturbance error term or residuals which represent divergence from long run relationship. $\hat{e}_t$ have to be stationary for cointegration between x_t and y_t to exist are saved and then used to estimate the second equation which takes the form of threshold autoregressive (TAR) regression (without augmentations)

$$\Delta\hat{\varepsilon}_t = I_t\theta_1\hat{\varepsilon}_{t-1} + (1 - I_t)\theta_2\hat{\varepsilon}_{t-1} + \nu_t \qquad \text{(ii)}$$

v_t is *i.i.d* white noise with zero mean. Δ is the difference operator, I_t is Heaviside indicator equal to 1 if $\hat{\varepsilon}_{t-1} \geq \tau$ and zero otherwise τ is the threshold value.

Can the adjustment process of the residuals, $\hat{e}_t$ be dynamic? Enders and Granger (1998) and Caner and Hansen (1998) suggest that the Heaviside indicator, I_t, can rely on the first difference of residuals ($\Delta\ \hat{e}_t$) as an alternative to levels ($\hat{e}_t$) we can develop Momentum-Threshold Autoregressive (MTAR) version of equation (ii) in which the Heaviside indicator, I_t, now takes the following form:

$$\Delta\hat{\varepsilon}_t = I_t\theta_1\Delta\hat{\varepsilon}_{t-1} + (1 - I_t)\theta_2\Delta\hat{\varepsilon}_{t-1} + \nu_t \qquad \text{(iii)}$$

To select between TAR and MTAR, we use the Bayesian information criterion (BIC) as recommended by Elders (2010) although Akaike information criterion (AIC) can also be used. The threshold value, τ is endogenously determined through a grid search as recommended by Chang (1993). We apply a trim of 15% on the upper and lower end of estimated residuals arranged in ascending order ($\hat{\varepsilon}_1, \hat{\varepsilon}_2, \hat{\varepsilon}_3 .....\hat{\varepsilon}_T$ where T is the number of observations.)

Table 3 indicates that in 75% of times (9/12 combinations), MTAR is identified as appropriate modeling to employ. Therefore, the asymmetric adjustment mechanism requires "steep" change in divergences as opposed to "deep" asymmetric adjustment associated with TAR (25% of time) modeling. The interesting results are that only CDS and Bond spreads (Indonesia, Malaysia and Tunisia) require TAR modeling.

Since θ_1 and θ_2 take different values, positive and negative divergences from equilibrium value are adjusted for at dissimilar speeds. In the long run, x and y should converge such that $\hat{e}_t = 0$. If $\hat{e}_t$ is above (below) equilibrium, it has to calibrate downwards (upwards) in the next period by $\theta_1\hat{e}_{t-1}(\theta_2\hat{e}_{t-1})$ to remain in equilibrium path.

If cointegration relationship is extant, then, $\theta_1 < 0$ and $\theta_2 < 0$. There are two perspectives of testing for cointegration namely (i) the joint hypothesis Φ(F) test where Ho: $\theta_1 = \theta_2 = 0$ (No co-integration between x and y). This null is evaluated using non-standard F-critical values provided by Enders and Siklos (2001). (ii) The t_{max} test statistic which is the larger of the t-statistic of θ_1 and θ_2. If the t_{max} is significantly negative, then both θ_1 and θ_2 are negative.

We also test, using the standard F-statistic, asymmetry in cointegration where Ho: $\theta_1 = \theta_2$ (symmetric cointegration relationship). The results of nonlinear cointegrations are tabulated in Table 4. We provide the interpretation using Turkey whose θ_1 and θ_2 are all statistically significant

From Table 3, the threshold or long run equilibrium values for Turkey are 7.07, –16.62 and –14.11. Let $\Delta\varepsilon_{t,CB}$, $\Delta\varepsilon_{t,CE}$, $\Delta\varepsilon_{t,EB}$, be the divergence from long-run equilibrium between CDS and bond spreads, CDS and equity and equity and bond spreads respectively. Then,

$$\Delta\varepsilon_{t,CB} = -0.34I_t(\varepsilon_{t-1,CB} - 7.07) - 0.277(I_t - 1)(\varepsilon_{t-1,CB} - 7.07) + \vartheta_{1t}$$

$$\Delta\varepsilon_{t,CE} = -0.167I_t(\varepsilon_{t-1,CE} + 16.62) - 0.107(I_t - 1)(\varepsilon_{t-1,CE} + 16.62) + \vartheta_{2t}$$

$$\Delta\varepsilon_{t,EB} = -0.061I_t(\varepsilon_{t-1,EB} + 14.11) - 0.109(I_t - 1)(\varepsilon_{t-1,EB} + 14.11) + \vartheta_{3t}$$

TABLE 3.Threshold values and Selection between TAR and MTAR

	CDS and BONDS				CDS and EQUITY				EQUITY and BONDS			
	TAR		MTAR		TAR		MTAR		TAR		MTAR	
Country	TH	BIC	TH	BIC	TH	BIC	TH	BIC	TH	BIC	TH	BIC
Indonesia	104.52	7237.57**	-10.08	7253.83	-131.57	7855.42	7.08	7808.387*	94.93	6702.26	-8.02	6653.348*
Malaysia	31.87	8581.73**	5.75	8593.99	-83.61	8451.61	3.89	8388.945*	-91.24	7854.93	-6.30	7836.479*
Turkey	57.57	10550.31	7.07	10381.22*	-365.96	12193.85	-16.62	12155.08*	-333.53	11582	-14.11	11565.54*
Tunisia	32.87	7872.49**	-5.67	7882.81	-141.64	9745.99	-6.69	9716.579*	-123.63	9805.49	11.11	9760.056*

Note: In Table 3, CDS is credit default swap. TAR is the threshold auto regressive (TAR) model while MTAR is momentum threshold auto regressive. TH is the threshold value selected using Bayesian Information criterion (BIC). The ** (*) indicates that model TAR (MTAR) was selected by BIC. The lower the BIC is, the better the model.

In relation to CB spread, when the spread between CDS and bond spread is increasing (decreasing) such that $\Delta\varepsilon_{t-1,CB} > 0$ ($\Delta\varepsilon_{t-1,CB} < 0$), the speed of adjustment in the upper (lower) regime [above (below) the threshold] is 34% (27.7%) . Similarly, when the spread between CDS and equity spread is increasing (decreasing) such that $\Delta\varepsilon_{t-1,CB} > 0$ ($\Delta\varepsilon_{t-1,CB} < 0$), the speed of adjustment in the upper (lower) regime [above (below) the threshold] is 16.7% (10.7%) .When the spread between equity and bond spread is increasing (decreasing) such that $\Delta\varepsilon_{t-1,CB} > 0$ ($\Delta\varepsilon_{t-1,CB} < 0$), the speed of adjustment in the upper (lower) regime [above (below) the threshold] is 6.1% (10.9%) .The speeds of adjustments are dissimilar in the upper and lower regime. Nonlinearity occurs because a shock to the system, for example, upper regime, could cause a shift from upper to lower regime. By consistently rejecting the null $\theta_1 = \theta_2$, we confirm these nonlinear cointegration and adjustment process to long run value or threshold. Since θ_1 of CDS-equity spread (Indonesia) and equity-bond spreads (Malaysia) are statistically insignificant, we can conclude that there is no adjustment mechanism in the upper regimes. The also applies to lower regime of CDS-bond spreads of Indonesia where θ_2 is insignificant.

All countries except Turkey have at least 2 out of 3 possible nonlinear cointegrations. The absence of non-linear cointegration could be attributed to a number of possible reasons. First, non-linear modeling is not appropriate for Turkey and hence we should employ linear modeling. Second, the three markets of these sovereign are highly illiquid such that minimal or no trading occurs. This is highly unlikely since Turkey's CDS and bonds are considered as relatively liquid and among the frequently trade sovereign among emerging markets. Third, the stock index or sovereign bond index are unsuitable proxies for evaluating credit risk (Chang-Lau and Kim 2004). Fourth, the countries have low sovereign debt levels and leverage (Low credit risk) hence equity and bond prices do not respond since their distance to default is very high. This is consistent with Merton (1974) explanation that equity prices react more to changes in credit risk for highly leveraged (high default risk) firms (countries). Anecdotal evidence (see the credit rating below) shows Turkey has relatively better credit rating (lower credit risk, lower leverage and higher distance to default), than Indonesia and Tunisia. However, it is Malaysia that should exhibit such unique results for its higher credit rating. These conflicting results could point to the unique nature of each country (Culture, economic and financial development, political stability, integration with global economy and government fiscal policies among others). Lastly, the level of market frictions and accompanying forces (capital immobility, regulations, taxes, transaction cost among others) could deter investors from engaging in arbitrage opportunities. Therefore, it is difficult for equilibrium relationship to be achieved for any pair of cointegrated securities.

ADOPTED[4] CREDIT RATING OF THE FOUR COUNTRIES**

Contry	Indonesia	Malaysia	Turkey	Tunisia
Credit rating	BB-	A-	BB	BBB

NONLINEAR SHORT RUN ADJUSTMENT DYNAMICS: THRESHOLD ERROR CORRECTION MODEL

The results of threshold cointegration imply that the adjustment dynamics of y_t in response to changes in x_t can be modeled using threshold error correction model.

TABLE 4. Short term asymmetric adjustment

Country	Bond spreads and CDS		Equity and CDS		Bond spreads and Equity	
Indonesia	BYS+=BYS-	***8.018	EQU+=EQU-	2.028	BYS+=BYS-	0.174
	CDS+=CDS-	***21.383	CDS+=CDS-	***7.21	EQU+=EQU-	***6.641
Malaysia	BYS+=BYS-	0.332	EQU+=EQU-	***18.809	BYS+=BYS-	0.523
	CDS+=CDS-	*2.620	CDS+=CDS-	*3.427	EQU+=EQU-	***10.009
Turkey	BYS+=BYS-	0.199	EQU+=EQU-	*3.626	BYS+=BYS-	0.142
	CDS+=CDS-	0.408	CDS+=CDS-	2.118	EQU+=EQU-	*3.156
Tunisia	BYS+=BYS-	***7.845	EQU+=EQU-	*3.854	BYS+=BYS-	*2.734
	CDS+=CDS-	0.151	CDS+=CDS-	1.297	EQU+=EQU-	0.003

Note: In this table BYS, CDS and EQU are bond spreads, credit default swap premium and equity respectively. (+) and (–) represent upper and lower regime. We test three pairs of short-term asymmetric adjustment process namely bond spreads and CDS, equity and CDS and equity. The short-term asymmetric adjustment process is tested as follows: All lags of y (x) in upper regime=all lags of y (x) in the lower regime and all lags of x (y) in upper regime=all lags of y(x) in the lower regime. ***, ** and * represent significance level at 1%, 5% and 10% respectively.

[4]Laura Jaramillo and atalina Michelle Tejad, Sovereign Credit Ratings and Spreads in Emerging Markets: Does Investment Grade matter?, Working Paper WP/11/44, IMF.

$$\Delta y_t = \alpha + \lambda^+ I_t EC_{t-1} + (1 - I_t)\lambda^- EC_{t-1} + \sum_{i=1}^{p} \delta_j \Delta y_{t-i} + \sum_{i=1}^{p} \delta_k \Delta x_{t-i} + \pi_{1t}$$

$$\Delta x_t = \alpha + \lambda^+ I_t EC_{t-1} + (1 - I_t)\lambda^- EC_{t-1} + \sum_{i=1}^{p} \delta_j \Delta y_{t-i} + \sum_{i=1}^{p} \delta_k \Delta x_{t-i} + \pi_{1t} \quad \text{(iv)}$$

In equation (iv), $EC_{t-1} = z_{t-1} = y_{t-1} - \beta_0 - \beta_1 x_{t-1}$ is the error correction term. In the next two sections, we use the following equation to analyze asymmetry in short run and long run adjustment processes in upper (above the threshold) and lower (below the threshold) regime. The short-run adjustment of $y_t(x_t)$ depends on parameters δ_j and δ_k. This implies that in the short run, the dynamics of $y_t(x_t)$ depends on its own past dynamics or/and the lagged outcome of $x_t(y_t)$.

According to results in Table 4, there is short run asymmetric adjustment process in 4/8 cointegrations between CDS premium and bond spreads. Again, Turkey shows no asymmetry in short run dynamic interaction between the two regimes. This implies that the markets are not informative with regard to credit risk in either upper or lower regime. The short run dynamic interaction between equity and CDS differs in the upper and lower regimes in 5/8 markets. Turning to bond spreads and equity, all countries except Tunisia have equity market responding to switches in regimes while bond market does not respond to regime changes in the short run. This is certainly because most investors in the sovereign bond markets are institutional investors who buy and hold the bond and only operate in the CDS market where short selling is easier and contract specifications and indentures do exist. It could also be that investors respond to fundamentals such as government fiscal policies (which take time) before trading in the bond market.

NONLINEAR PRICE DISCOVERY AND LONG RUN ADJUSTMENT DYNAMICS

To test for long-run adjustment, we use the parameters λ^+ and λ^-. We test the Ho: $\lambda^+ = \lambda^-$. Rejection of the null is a bellwether of different speed of adjustment of y_t to new information in upper and lower regime. We then test for regime-specific price discovery and informativeness of each security.

To test for price discovery and long run cointegration in the upper regime, we assess the statistical significance, the sign and size of the parameters λ^+ and λ^-. The two measure the speed of adjustment to new information above and below the threshold respectively Engle and Granger, (1987) postulated that the existence of cointegration means that at least one market has to adjust to new information before the other market. This test complements any inconclusive evidence provided by the co-integration.

If both λ^+ and λ^- are statistically significant, then both markets y and x respond to new credit risk information almost at the same time (price discovery takes place in both markets) in the upper (lower) regime. If $\lambda^+(\lambda^-)$ is significantly negative (positive), $y_t(x_t)$ adjusts to new information to clear misalignment or pricing discrepancy with $x_t(y_t)$. Therefore, price discovery occurs in market $x_t(y_t)$ in the upper regime. The same arguments and tests are then replicated for lower regime. After assessing which market is more informative or plays the price discovery leadership role under different regimes, we

TABLE 5. Nonlinear cointegration

	Variables	θ_1	θ_2	DW	$\theta_1 = \theta_2 = 0$	$\theta_1 = \theta_2$
Indonesia						
TAR	CDS/Bond	***-0.034	-0.003	1.98	***15.24	*11.88
MTAR	CDS/Equity	-0.198	***-0.186	2.03	0.04	*23.09
MTAR	Equity/Bond	***-0.103	***-0.249	1.97	***7.08	*23.37
Malaysia						
TAR	CDS/Bond	***-0.042	***-0.021	2.00	**3.66	*16.37
MTAR	CDS/Equity	***-0.102	***-0.225	1.98	***7.48	*32.45
MTAR	Equity/Bond	-0.017	**-0.082	2.00	*2.09	*3.32
Turkey						
MTAR	CDS/Bond	***-0.340	***-0.277	2.00	*2.11	*105.67
MTAR	CDS/Equity	***-0.167	***-0.107	2.01	1.76	*18.81
MTAR	Equity/Bond	*-0.061	***-0.109	2.00	1.1	*7.65
Tunisia						
TAR	CDS/Bond	***-0.074	**-0.017	2.13	***17.05	*23.84
MTAR	CDS/Equity	***-0.152	***-0.089	2.01	1.79	*13.81
MTAR	Equity/Bond	***-0.185	***-0.107	2.00	*2.75	*19.57

Note: θ_1 and θ_2 are parameter estimates of equation iv. The critical F values for the Ho: $\theta_1 = \theta_2 = 0$ is non-standard and is provided by Ender and Granger (1998). The F-statistic for the Ho: $\theta_1 = \theta_2$ is compared with standard F-critical values. ***, ** and * are significance levels of 1%,5% and 10% respectively.

TABLE 6. Nonlinear price discovery and long run adjustment process

Panel A					
BS and CDS		Indonesia	Malaysia	Turkey	Tunisia
BYS	λ^{+}_{t-1}	-0.0028	**0.0125	*0.0183	-0.0024
	λ^{-}_{t-1}	-0.0010	**0.0167	-0.0011	***-0.0107
Ho: $\lambda^{+}_{t-1} = \lambda^{-}_{t-1}$	F-stat	0.1020	0.191	*8.517	**4.037
LB(4) and DW		1.00 and 2.00	1.00 and 2.00	0.99 and 1.98	0.95 and 1.99
CDS	λ^{+}_{t-1}	*-0.0207	-0.0085	0.0052	-0.0063
	λ^{-}_{t-1}	***-0.0117	-0.0023	*-0.0130	**0.0125
Ho: $\lambda^{+}_{t-1} = \lambda^{-}_{t-1}$	F-stat	0.9430	0.3490	***3.445	0.7090
LB(4) and DW		1.00 and 1.99	0.00 and 2.09	0.90 and 1.99	0.99 and 2.00
Linear λ	BYS	-0.0018	*-0.0179	***-0.0099	*0.8627
	CDS	**0.0024	*0.0220	**0.0087	**0.0616
Panel B					
CDS and Equity		Indonesia	Malaysia	Turkey	Tunisia
CDS	λ^{+}_{t-1}	*0.0251	*-0.0082	0.0001	*-0.0045
	λ^{-}_{t-1}	**-0.0105	*-0.2484	0.0001	*0.0558
Ho: $\lambda^{+}_{t-1} = \lambda^{-}_{t-1}$	F-stat	*11.497	*149.973	0.0000	*14.339
LB(4) and DW		0.67 and 2.01	0.31 and 2.06	0.92 and 1.99	0.93 and 1.99
EQU	λ^{+}_{t-1}	0.0007	0.0052	***0.0008	0.0117
	λ^{-}_{t-1}	0.0015	*0.7913	-0.0017	-0.0987
Ho: $\lambda^{+}_{t-1} = \lambda^{-}_{t-1}$	F-stat	0.0230	*23.839	**4.926	0.1900
LB(4) and DW		0.67 and 2.01	0.98 and 2.01	1.00 and 1.99	0.21 and 1.96
Linear λ	CDS	*-0.0359	**-0.0068	-0.0027	**-0.0049
	EQU	-0.0054	*-0.0031	***-0.0025	-0.0018
Panel C					
BYS and Equity		Indonesia	Malaysia	Turkey	Tunisia
BYS	λ^{+}_{t-1}	***0.0251	***-0.0082	*0.0185	**-0.0028
	λ^{-}_{t-1}	**-0.0105	***-0.2484	**-0.0054	0.1127
Ho: $\lambda^{+}_{t-1} = \lambda^{-}_{t-1}$	F-stat	***11.497	***149.973	**4.406	0.1360
LB(4) and DW		0.67 and 2.01	0.31 and 2.06	0.93 and 1.99	1.00 and 1.99
EQU	λ^{+}_{t-1}	0.0007	0.0052	*-0.0396	0.0206
	λ^{-}_{t-1}	0.0015	***0.7913	0.0038	***-45.97
Ho: $\lambda^{+}_{t-1} = \lambda^{-}_{t-1}$	F-stat	0.0230	***23.839	**4.647	***25.787
LB(4) and DW		0.67 and 2.01	0.98 and 2.01	0.95 and 1.99	0.21 and 2.02
Linear λ	BYS	***-0.0359	**-0.0068	***-0.0070	-0.0006
	EQU	-0.0054	***-0.0031	-0.0002	**0.0009

Note: This table provides summary information on asymmetrical price discovery between CDS and bond spreads. BS and CDS are bond spreads and credit default swap. DW is Durbin Watson statistic which test the null of no (zero) autocorrelation in the residuals. LB(4) is the Ljung-Box statistic which test the null of no autocorrelation in residuals up to four lags. Ho: λ^{+}_{t-1} and λ^{-}_{t-1} is the error correction term (speed of adjustment parameter) in upper and lower regime respectively. Each series (BS and CDS) adjusts to long-run equilibrium relationship in two regimes (above and below the threshold. The null hypothesis, Ho: Ho: $\lambda^{+}_{t-1} = \lambda^{-}_{t-1}$ is a test of asymmetry in error or deviation adjustment process. *, ** and *** is 1%, 5% and 10% significance level. Linear λ is the error correction term in a linear model which assumes a single regime.

compare the results with a linear ECM model. The results are shown in Table 5.

Panel A in Table 6 shows the results of price discovery in lower and upper regimes when considering cointegration between bond spreads and CDS premium. We evaluate Malaysia's λ^{+}_{t-1} for both BYS (0.0125) and CDS (–0.0085). In the upper regime, BYS speed of adjustment parameter (0.0125) is significantly positive while CDS speed of adjustment parameter (–0.0085) is insignificantly negative. Therefore, BYS adjusts to incorporate new information hence price discovery occurs in the CDS market. Using the same argument, price discovery takes place in bond market in Indonesia (–0.0028 is insignificantly negative) and in CDS market in Turkey (0.0052 is insignificantly positive). In Tunisia's upper regime, bond spreads and CDS premium do not respond to credit risk information certainly because the market is so illiquid to price credit risk or only the more liquid equity market respond to such credit risk information. In the lower regime λ^{-}_{t-1} price discovery takes place in bond markets in Indonesia and Turkey while in Malaysia and Tunisia, price discovery takes place in CDS markets. Using the linear VECM, price discovery takes place in both markets except in Indonesia. Therefore, linear and nonlinear price discovery yield contradictory results.

Turning to panel B (CDS and equity markets) upper and lower regimes, price discovery takes place in equity market except in Turkey where CDS premium is the more informative. Using the linear modeling, the results are consistent with nonlinear modeling in Indonesia and Tunisia and contradict results for Malaysia and Turkey. In panel C, (bond spread and equity) upper regime, price discovery takes place in equity market in all countries. In fact, in Turkey, price discovery takes place in both bond and equity markets (λ^{+}_{t-1}) for BYS and EQU are significant). In the lower regime (λ^{-}_{t-1}), price discovery takes place in both bond and equity markets in Malaysia, in the equity market in Indonesia and Turkey and in the bond market in Tunisia. All The results are consistent with linear modeling.

Lastly, we test whether there is asymmetry in price discovery process by testing the null of: $\lambda^{+}_{t-1} = \lambda^{-}_{t-1}$. In 14/24 possible combinations, we find evidence of asymmetric price discovery process which is regime specific. Indonesia and Tunisia, both with the lowest credit rating (high default risk) have only 2/6 possible asymmetries in price discovery. While they are expected to exhibit higher number of asymmetries, the result indicate that they may be illiquid in both regimes. Malaysia and Turkey, with better credit rating (lower default risk) have 4/6 asymmetries in price discovery processes. This means that the markets are certainly efficient in pricing credit risk in one of the regimes or are simply more liquid as momentum occurs in one regime and investors trade more in one regime relative to the other hence the higher number of asymmetries.

The nonlinear error correction mechanism for Indonesia CDS and Malaysia bond yield spread (BYS), (both of which λ^{+}_{t-1} and λ^{-}_{t-1} are statistically significant and TAR modeling was selected) can be interpreted as follows: Given the threshold or long run values of 104.52 and 31.87 respectively, then

$$\Delta CDS_t(Indonesia) = -0.02071 I_t(z_{t-1} - 104.52) - 0.0117(1 - I_t)(z_{t-1} - 104.52) + \varepsilon_{1t}$$

$$\Delta BYS_t(Malaysia) = -0.0125 I_t(z_{t-1} - 31.87) + 0.002(1 - I_t)(z_{t-1} - 31.87) + \varepsilon_{2t}$$

When the divergence between CDS and bond spreads are increasing (decreasing) in Indonesia so that $z_{t-1,CB} > 0$ ($z_{t-1,CB} < 0$), CDS premium decreases by 2.07% (1.17%) to correct divergence from long run value of 104.52. Similarly, when the divergence between CDS and bond spreads are increasing (decreasing) in Malaysia so that $z_{t-1,CB} > 0$ ($z_{t-1,CB} < 0$), BYS increases by 1.25% (0.2%) in the next period to correct divergence from threshold or long-run value of 31.87.

CONCLUSION

In this study, we investigate whether sovereign CDS premium, bond spreads and equity prices are characterized by nonlinearities including non-linear unit root. We document evidence of nonlinearities. We thus proceed to investigate non-linear cointegration relationship between any two series (CDS and bonds, CDS and equity and equity and bonds spreads). We find existence of threshold and of momentum (in 12/12 cointegrations) whereby error term deviation from long term equilibrium between any two series evince more momentum in one direction (regime) relative to substitute direction. This means that positive and negative deviations from long run equilibrium relationship can be adjusted for at different speeds. In 10/12 cointegrations, MTAR was identified as the appropriate modeling tool to investigate non-linear dynamic interactions among the markets.

The absence of non-linear cointegration in Turkey may indicate that the sovereign have very low level of debt (low credit risk) hence equity prices and bond spreads respond to country's fundamentals rather than to credit risk information. Anecdotal evidence does not support this view of lower credit risk for Turkey. Other possible reason could be that either the markets are high illiquidity or linear as opposed to non-linear modeling is suitable for Turkey or severe market frictions prevent utilization of arbitrage opportunities to achieve long run equilibrium relationship between any two markets in both regimes. Moreover, we could also conclude that the CDS premium, bond spreads and equity markets are not suitable proxies for modeling credit risk.

We find evidence of asymmetric short term adjustment process which differ with regimes in 14/24 possible outcomes. This could be interpreted mean that the time span for regime switch may be longer than the time it takes independent variables to respond to positive and negative external shocks. Price discovery and speed of adjustments to new information are generally regime specific. Every country in the sample has at least two asymmetric adjustment processes. Nonlinear and linear price discovery mechanisms yield contradicting results except for cointegration relationship between equity and bond spreads. The findings of this study contradict the findings of Chan-Lau and Kim (2004) but support the rational for their findings. We also complement assertions by Delatte et al. (2010) and the findings of Acharya and Johnson (2007).

The study can also be extended to investigate the role of liquidity in non-linear cointegration, price discovery process and speed of adjustment process in different regimes. The use of TVECM could also help explain the role of transaction costs in each regime and how market frictions affect the dynamic interaction among the three markets.

REFERENCES

Acharya,V., & T. C. Johnson. 2007. Insider Trading in Credit derivatives. *Journal of Financial Economics* 84: 110-141.

Aktug, E., Geraldo, V. & Bae, Y. 2008. The Dynamics of Sovereign Credit Default Swap and Bond Markets: Empirical Evidence from the 2001-2007 Period. Working paper. Lehigh University.

Ammer, J. & Cai, F. 2008. Sovereign CDS and bond pricing dynamics in emerging markets: Does the cheapest-to-deliver option matter? Board of Governors of the Federal Reserve System, International Finance Discussion Papers, Number 912.

Anderson, H. 1997. Transaction costs and non-linear adjustment towards equilibrium in the U.S. Treasury Bill market. *Oxford Bulletin of Economics and Statistics* 59(4): 465-484.

Anne-Laure, D., Gex, M. & López-Villavicencio, A. (2010). *Has the CDS market amplified the European sovereign crisis? A non-linear approach.*Working paper.

Asquith., P., Gertner, R. & Sharfstein, D. 1994. Anatomy of financial distress: An examination of junk-bond issuers. *Quarterly Journal of Economics* 109: 625-658.

Balke, N. & Fomby, T. 1997. Threshold cointegration. *International Economic Review* 38: 627-645.

Bekaert, G. & Harvey, C. 2002. *EmergingMarkets Finance.* Working paper. National Bureau of Economic Research (NBER).

Berndt, A. & Anastasiya, O. 2007. Information Flow between Credit Default Swap, Option and Equity Markets Working Paper. Carnegie Mellon University.

Blanco, R., Brennan, S. & Marsh, I. 2005. An empirical analysis of the dynamic relationship between investment-grade bonds and credit default swaps. *Journal of Finance* 60(5): 2255-2281.

Brock, W. A. & Sayers, C. L. 1988. Is the business cycle characterized by deterministic chaos? *Journal of Monetary Economics* 22(1): 71-90.

Campbell, J. Y. & Taksler, G. B. 2003. Equity volatility and corporate bond yields. *Journal of Finance* 58(6): 2321-2350.

Caner, M. & Hansen, B. 1998. Threshold Auto regression with a Near Unit Root. University of Wisconsin Working Paper: *mimeo*.

Chan, K. S. 1993. Consistency and limiting distribution of the least squares estimator of a threshold autoregressive model. *The Annals of Statistics* 21: 520-533.

Chan Kam, C., Fung, H. & Zhang, G. 2009. On the relationship between asian credit default swap and equity markets. *Journal of Asia Business Studies* 4(1): 3-12.

Chan-Lau, J. A., & S. K, Yoon. 2004. Equity Prices, Credit Default Swaps, and Bond Spreads in Emerging Markets. Working Paper, International Monetary Fund.

Cremers., M., Driessen, J., Maenhout, P. & Weinbaum, D. 2004. Explaining the Level of Credit spreads: Option-Implied Jump Risk Premia in a Firm Value Model. Working Papers No 191 BIS.

Denis., D. J. & Denis, D. 1995. Causes of financial distress following leveraged recapitalization. *Journal of Financial Economics* 27: 411-418.

Duffie, D. 1999. Credit swap valuation. *Financial Analysts Journal* January-February: 73-87.

Elliot, G., Rothenberg, T. J. & Stock, J. H. 1996. Efficient tests for an autoregressive unit root. *Econometrica* 64(4): 813-836.

Enders, W. & Siklos, P. L. 2001. Cointegration and threshold adjustment. *Journal of Business Economics & Statistics* 19:166-176.

Enders, W. & Granger, C.W. 1998. Unit-root tests and asymmetric adjustment with an example using the term structure of interest rates. *Journal of Business Economics & Statistics* 16: 304-311.

Engle, R. & Sheppard, K. 2001. Theoretical and Empirical properties of Dynamic conditional correlation Multivariate GARCH. Working Paper No. 8554, National Bureau of Economic Research.

Engle, R. & Granger, C. 1987. Cointegration and error correction: Representation, estimation and testing. *Econometrica* 55: 251-276.

Fama, E. F. 1965. The behavior of stock market returns. *Journal of Business* 38: 34-105.

Fama, E. F. & French, K. R. 1989. Business conditions and expected returns on stocks and bonds. *Journal of Financial Economics* 25: 23-49.

Fama, E. F. & French, K. R. 1996. Multifactor explanations of asset pricing anomalies. *Journal of Finance* 51: 55-84.

Fischer, B. 1976. Studies of stock market volatility changes. Proceedings of the American Statistical Association, Business and Statistics Section, 177-181

Fleming, M. J. & Remolona, E. M. 1997. What moves the bond market? Economic Policy Review*, Federal Reserve Bank of New York* Dec: 31-50.

Forte, S. 2008. Calibrating Structural Models: A New Methodology Based on Stockand Credit Default Swap Data. Working Paper.

Forte, S. & Peña, J.I. 2008. Credit Spreads: An Empirical Analysis on the Informational Content of Stocks, Bonds and CDS. Working Paper.

Forte, S. & L. Lovreta. 2008. *Credit risk discovery in the stock and CDS market: who,when and why leads*. Working paper. Universitat Ramon Llull.

Franses, P. & Dijk, D. van. 2000b. Nonlinear Econometric Modeling in Time Series. Proceedings of the Eleventh International Symposium in Economic Theory. Cambridge University Press, Cambridge.

French, K. & Roll, R. 1986. Stock return variances: The arrival of information and the reaction of traders. *Journal of Financial Economics* 19: 3-30.

Gomez, D. & Nikolov, B. (2003). *Pricing the Risk of Default: Are Bonds Enough?*Working paper,University of Laussane.

Hall, A., Anderson, H. & Granger, C. 1992. A cointegration analysis of treasury bill yields. *The Review of Economics and Statistics* 74: 116-126.

Hommes, C. & Florian, W. 2009. Complex evolutionary systems in behavioral finance. In *Handbook of Financial Markets: Dynamics and Evolution*, edited by: Hens, T. and Schenk-Hoppé, K. R., 217-276. Amsterdam: North-Holland.

Hull, J. C., & White, A. 2000a. Valuing Credit Default Swaps I: No Counterparty Default Risk. *Journal of Derivatives* 8(1): 29-40.

Hull, J. C., & White, A. 2000b. Valuing Credit Default Swaps I: No Counterparty Default Risk. *Journal of Derivatives* 8(3): 12-22.

Hull, J., Predescu, M. & White, A. 2004. The relationship between credit default swap spreads, bond yields and credit rating announcements. *Journal of Banking and Finance* 28(11): 2789-2811.

Hung-Gay, F., Sierra, G. E., Yau, J. & Zhang, G. 2008. Are the U.S. stock market and credit default swap market related? Evidence from the CDX indices. *The Journal of Alternative Investments* 11(1): 43-61.

Ihle, R. & Cramon-Taubadel, S, V. 2008. A Comparison of Threshold Cointegration and Markov-Switching Vector Error Correction Models in Price Transmission Analysis. *Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting and Market Risk Management.*

Johansen, S. 1988 .Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control* 12(1988): 231-254.

Johansen, S. & Juselius, K. 1990. Maximum likelihood estimation and inference on cointegration-with application to the demand for money. *Oxford Bulletin of Economics and Statistics* 5(2): 169-210.

Kapetanios, G., Yongcheol, S. & Snell, A. 2003. Testing for a unit root in the nonlinear STAR framework. *Journal of Econometrics* 112: 359-379.

Lehmann, B. N. 2002. Some desiderata for the measurement of price discovery acrossMarkets. *Journal of Financial Markets* 5(3): 259-276.

Lee V., Fang, V. & Chien-Ting Lin, N. 2007. Volatility linkages and spillovers in stock and bond markets: Some international evidence. *Journal of International Finance and Economics* 7(1): 1-10.

Lo, M. C. & Zivot, E. 2001. Threshold cointegration and nonlinear adjustment to the law of one price. *Macroeconomic Dynamics* 5(4): 533-576.

Longstaff, F. A., Mithal, S. & Neiss, E. 2005. Corporate yield spreads: Default risk or liquidity? New evidence from the credit default swap market. *Journal of Finance* 60: 2213-2253.

Lindén, S. 2010. The price and risk effects of option introductions on the Nordic markets forthcoming, European Economy, Economic Papers 434, 2010.

Mandelbrot, B. 1963. The variation of certain speculative prices. *Journal of Business* 36: 394-419.

Marshall, D. 1994. Asset return volatility with extremely small costs of consumption adjustment. Working Paper Series, Macroeconomic Issues 94-23, Federal Reserve Bank of Chicago.

Meng., L., Gwilym, O. & Varas, J. 2009. Volatility transmission among the CDS, equity and bond markets. *Journal of Fixed Income* 18(3): 33-46.

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

Norden, L. & Weber, M. 2004. Informational efficiency of credit default swap and stock markets: The impact of credit rating announcements. *Journal of Banking and Finance* 28(11): 2813-2843.

Norden, L. & Weber, M. 2009. The co-movement of credit default swap, bond and stock markets: An empirical analysis. *European Financial Management* 15(3): 529-562.

Opler, T. & Titman, S. 1994. Financial distress and corporate performance. *Journal of Finance* 49: 1015-1040.

Pan, J. & Singleton, K. J. 2008. Default and recovery implicit in the term structure of sovereign CDS spreads. *Journal of Finance* 63: 2345-2384.

Realdon, M. 2008. Credit default swap rates and stock prices. *Applied Financial Economics Letters* 4(4): 241-248.

Rubinstein, A. 1998. *Modeling Bounded Rationality*. Massachusetts: MIT Press.

Simon, H. 1991. Bounded rationality and organizational learning. *Organization Science* 2(1):125-134.

Scheffel, M. E. 2008. Evaluating forecasts of interest rates in linear and non-linear error-correction frameworks. Working paper.

Stock, J. & Watson, M. 1999 . *Cointegration, Causality and Forecasting: A Festschrift in Honour of Clive Granger*. Oxford: Oxford University Press.

Stein, J. 1987. Informational externalities and welfare-reducing speculation. *Journal of Political Economy* 95: 1123-1145.

Tong, H. 1978. *On a Threshold Model in Pattern Recognition and Signal Processing*. Amsterdam: Sijhoff, Noordhoff, Amsterdam.

Trinkler, C. & Wolf, N. 2003. Economic Integration in Interwar Poland - A Threshold Cointegration Analysis of the Law of One Price for Poland 1924-1937. Economics Working Papers ECO2003-05, European University Institute.

Tsay, R. 1986. Nonlinearity tests for time series. *Biometrica* 73: 461-466.

Tsay, R. 1998. Testing and modeling multivariate threshold models. *Journal of American Statistical Association* 93: 1188-1202.

Vavra, P & Goodwin, B. K. 2005. Analysis of Price Transmission along the Food Chain. OECD Food, Agriculture and Fisheries Working Papers, No. 3, OECD Publishing.

Vassalou, M. & Xing, Y. 2004. Default risk in equity returns. *Journal of Finance* 59(2):831-868.

Yu, F. 2006. How Profitable is capital structure arbitrage. *Financial Analysts Journal* 62:47-62.

Zhang, F. X. 2008. Market expectations and default risk premium in credit default swap prices: A study of Argentine default. *Journal of Fixed Income* 18(1): 37-55.

Zhang B. Y, Zhou, H. & Zhu, H. 2005. Explaining Credit Default Swap Spreads with Equity Volatility and Jump Risks of Individual Firms. BIS Working Paper No 181.

Zhu, H. 2006. An empirical comparison of credit spreads between the bond market and the credit default swap market. *Journal of Financial Services Research* 29: 211-235.

Geoffrey Ngene
Stetson School of Business and Economics
Mercer University
1400 Coleman Avenue
Macon, GA 31207
ngene_gm@mercer.edu

M. Kabir Hassan
Department of Economics and Finance
University of New Orleans
New Orleans, LA 70148, USA
mhassan@uno.edu;
KabirHassan63@gmail.com