Original Article

Commodity futures indexes and related exchange traded notes: Linear and nonlinear adjustment

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Abdullah M. Noman

obtained an MSc in Economics and Finance from University of Bristol, UK and PhD from the Department of Economics and Finance, University of New Orleans. He is currently on the faculty of the Department of Economics, Tulane University, New Orleans.

M. Nakibur Rahman

holds an M.Sc. in Information System from University of Maine, USA. He obtained his PhD from the Department of Economics and Finance, University of New Orleans and is currently on the faculty of the Department of Economics, Tulane University, New Orleans.

Correspondence: Abdullah M. Noman, Department of Economics and Finance, University of New Orleans, Louisiana, LA 70148, USA.
E-mail: anoman@uno.edu

ABSTRACT Recent financialization of the commodity futures markets has led to the introduction of exchange traded products (ETP) that are directly linked to some underlying commodity futures contracts. One such ETP is known as exchange traded notes (ETN). This article examines the long-run relationship between a set of 19 ETN markets and their underlying commodity futures indexes. It also investigates whether the long-run adjustment process is linear or nonlinear. The article employs daily data spanning from January 2009 to December 2011, and utilizes the Engle–Granger cointegration framework allowing for linear and nonlinear adjustment processes through the error correction term. The results indicate the existence of long-run cointegration between ETN prices and the values of their underlying commodity indexes. The long-run adjustment processes between these markets, however, exhibit nonlinearity, which can be attributed to a number of factors including the time lag involved in the process of creation and redemption of share units of an ETN.

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INTRODUCTION

Commodity futures as an investment choice have recently gained prominence. An increasing number of investors are finding their way into commodity futures markets, either directly or through some other markets that are linked to

them. According to some recent studies, the size of the investment in the commodity markets through the index products only stands somewhere over US\$170 billion dollars (Stoll and Whaley, 2010)¹. The literature cites a number of reasons for investing in commodity futures in

general. A widely cited incentive for investing in commodities is that it provides investors with the necessary diversification tool. Adding some commodities to a portfolio with traditional assets has been shown to reduce risks significantly (Bodie and Rosansky, 1980). Another motivation is that commodities can potentially be used as a hedge against inflation (Bodie, 1983).

A recent development in the commodity futures markets is their financialization. Traditionally, commodity futures markets were domains for hedgers only wishing to hedge against adverse movement of the commodity prices. Now investors with other motives are increasingly entering into these markets, with a number of new avenues currently available to them. The introduction of a new class of products, known as the exchange traded products (ETP), has facilitated investment in the commodities at competitive costs compared to futures markets that involve margin requirements. An exchange traded note (ETN)² is a debt-based ETP that aims to track performances of some underlying assets that can be anything from the class of equity, bond and commodity indexes.

It is worth noting that the creation and operation of ETP based on some underlying asset markets leads to the existence of a theoretical link between the ETP and their underlying assets. This theoretical link may not be entirely like that of a spot-futures relationship through the cost of carry models that is driven by arbitrage opportunities. In traditional cost of carry models, the commodity index is the futures asset and an ETP is the asset in the spot market³. On the other hand, the commodity futures index that we consider here is itself an underlying asset. Nevertheless, there could still be a conceivable theoretical linkage between ETN and their underlying assets. This relationship may be based on a rational expectation hypothesis according to which the investors measure the

value of an ETN based entirely on the value of its underlying asset⁴. As the value of the underlying asset, say a commodity futures, changes over time, this new information is continuously impounded in the value of the linked Exchange Traded Fund (ETF) or ETN market. Investors are then able to predict the value of the ETF or ETN without making systematic errors. A relevant question in relation to the ETP is that of whether these products display an empirical linkage with their underlying assets markets. At the minimum, one could expect a long-run stable relationship between these markets so that price movements of these assets are cointegrated over time. A stronger aspect of this relationship could imply rational assessment and prediction ability of investors in the ETP markets so that it is only the movements in the underlying asset values that would be responsible for any movements in the linked ETP.

The objective of this article is to examine the adjustment process between commodity futures markets and other markets that are linked to the performance of these commodity futures. In particular, we investigate the long-run relationship between a set commodity futures indexes and ETN that are linked to these commodity future indexes. The commodity indexes that we consider here belong to the Dow Jones (DJ) family of indexes, also known as the DJ-UBS indexes. The ETN considered here track these indexes as their benchmarks and are issued by iPath sponsored by Barclays Capital. We examine the long-run relationship among these markets within the Engle-Granger (EG) cointegration framework. We test the existence of a cointegrating relationship between two markets allowing for both linear and nonlinear adjustment processes.

The article contributes to the existing literature in a number of ways. First and foremost, to the best of our knowledge this is the

first study examining the long-run relationship among the commodity futures markets and the ETN based on these commodity futures indexes. The results of the article have potential benefits for investors for both of the markets. It has been some time since the commodity futures-based ETN products were introduced, and no such study has been undertaken to investigate whether these markets are closely related to each other. Second, this article extends the literature in the area of financial market integration to include commodity futures indexes and related markets. Third, the article makes some methodological contribution to the existing literature in the sense that only a few papers have employed a nonlinear adjustment mechanism to study the long-run relationship in commodity futures markets.

The main findings of the article suggest that for the ETN that we examine here the prices are cointegrated with the values of the underlying indexes. However, the adjustment processes between them are nonlinear, rather than linear. The explanation for this nonlinear adjustment between prices in these two markets may be attributed to a particular feature of ETN that involves time lag in the process of creation and redemption of units of a particular ETN. The remainder of the article is organized as follows. The second section reviews the relevant literature, the third section discusses the hypotheses of the article and the fourth section presents details on the data and the estimation methodology. The fifth section presents results and analysis of the findings, while the final section concludes the article.

BRIEF REVIEW OF EXISTING LITERATURE

The existing literature documents an active discussion as to whether one should expect any

benefit from investing in commodity futures. In other words, the question the literature revolves around is whether commodity investment can be considered as a distinct asset class in the same sense as conventional asset classes are defined that include equity, bonds, real estate and so on. Proponents of commodity investments claim that commodity futures products could potentially be included in one's well-diversified portfolio. The idea dates back to the works of Bodie and Rosansky (1980) and is discussed in such recent studies as Jensen *et al* (2000), Erb and Harvey (2006), Gorton and Rouwenhorst (2006), Geman and Kharoubi (2008), Büyüksahin *et al* (2010) and Chong and Miffre (2010). The argument is that returns in the commodities markets are driven by factors that are different from those that affect the other asset classes (Daskalaki and Skiadopoulos, 2011). Although Cheung and Miu (2010) find some diversification benefits of commodity futures, they argue that these benefits are not universal. They suggest that only conservative investors will benefit from diversification with commodity futures, which would help them avoid high risks of financial market investments.

Another strand of the literature investigates whether different commodity markets are linked to each other. Chng (2009) mentions a number of ways in which commodity markets can be linked to each other. There are two broad ways commodity markets can be related to other, namely, fundamental and empirical. Examples of the fundamental linkage include spot and futures markets, spot and options markets, and futures and options markets. On the other hand, two markets can be empirically linked to each other, for example, equity and oil markets (Driesprong *et al*, 2008), gold and silver markets (Ciner, 2001) and so on. Chng (2009) examines links among a group of commodities that are used in the

automobile industry as input *vis-à-vis* returns on equities and find evidence of some linkages between these markets.

Traditionally, commodity futures markets have been the domain of commercial hedgers wishing to hedge their positions from adverse movements of commodity prices. Commercial hedgers are still big traders in the commodity futures markets. However, the recent financialization of the commodity futures markets has brought different types of investors to the commodities markets (Tang and Xiong, 2010). For example, portfolio investors might want to diversify their exposure by adding commodity-related assets. Yet another type of investor might simply want to enhance their returns by speculating movements in the commodity prices. There is more than one way to get exposed to movements in commodity prices. A popular way to enter into commodities markets is to invest in long-only commodity futures, which can be either an individual commodity such as gold or oil, or a basket of commodities, usually an index. Two widely followed commodity futures indexes are the DJ-UBS Commodity Index and the S&P Goldman Sachs Commodity Index. The commodity futures market now has wide frontier stretching to include a number of other markets that are linked to commodity futures. For example, more than a hundred ETP are now offered that derive their value from the underlying commodity-based assets, both broad indexes and individual commodities (Cheung and Miu, 2010). Two such ETP are ETF and ETN.

Unlike ETF, which are equity products, ETN are debt instruments⁵. More specifically, ETN are unsecured debt products issued by investment or asset management firms. Though the first ETN was introduced in 2006 by Barclays PLC, with the

trade name of 'iPath' and commodity futures index as the underlying benchmark, these instruments can have other types of assets as underlying benchmarks including foreign currency-based assets. ETN are traded in the secondary market like ETF after issuance, but unlike ETF they do not hold actual commodities. There are around 100 ETN traded on different exchanges around the globe. Investors in an ETN get a return that equals the percentage change in the price of the underlying asset less the management fee, which is calculated on a daily basis.

Like the products themselves, academic literature on ETN is in its initial phase and only a few studies are available that directly address the pricing issue. Geman *et al* (2012) present a comparative study of ETN relative to other ETP, especially ETF. They find that ETN are becoming popular for their attractive features, although their expenses are not always lower than their competitor ETP. Washer and Jorgensen (2011) investigate the impact of credit risk on the demand and redemption of ETN shares. Using weekly data from June 2006 through June 2009, they find that a number of outstanding shares are affected by the credit risk spread. Aroskar and Ogden (2012) study the tracking ability of ETN in replicating the performance of their underlying benchmark. They find that ETN are very successful in tracking the returns on their benchmark. Cserna *et al* (2012) show that although credit risk should be priced, the actual ETN prices do not seem to reflect this. The authors link their results to the behavioral biases of the investors.

THE HYPOTHESES

The focus of this article is on the long-run relationship between ETN and the assets whose

performance these products aim to track. Because of the intraday trading facility and return-seeking investors, the markets under investigation are expected to be closely linked to each other. Any pricing model that captures this close link between market values of ETN and their underlying benchmarks, however, assumes that there is no uncertainty in the redemption by the investors and therefore no default risk. This one-for-one relationship is, however, true only in the long run. In the short run, there may exist nontrivial mispricing that may be due to a number of reasons, including the share creation and redemption process (Wright *et al*, 2010), investor risk perception and sentiment (Baker and Wurgler, 2007), and limits of arbitrage (Shleifer and Vishny, 1997). The short-run deviation of market price from the indicative value is then defined as the premium (or discount) and can be found in the relevant literature on closed-end funds (Pontiff, 1997; Gemmill and Thomas, 2002; Flynn, 2010); ETF (Delcours and Zhong, 2007).

Even when there exists long-run correspondence between the market values of an asset and its underlying benchmark, the adjustment process between them may or may not be linear. There may exist some degree of nonlinearity in the adjustment process between the market values of an ETN and the value of the underlying assets⁶. A potential source of the nonlinear adjustment process is the presence of the investor's fees, management fees and other trading costs. These costs are even substantial for ETN products where investor fees are calculated on a daily basis. Even if the transaction costs today are not large as such, investors often have to buy and redeem shares and notes in bulk⁷. A second source of nonlinear relationship is the existence of heterogeneous investors (Tang and Xiong,

2010). The existence of such diverse types of investors in the commodity markets may introduce nonlinearities in the adjustment between financial products in the markets under investigation⁸. A third possible source of nonlinearity is the process of share creation and redemption for ETN. For an ETN, it may take several days for creation and redemption of the assets⁹ (Wright *et al*, 2010; Diavatopoulos *et al*, 2011). The reasons above may create some band of inertia within which any mispricing between two markets is not corrected, but rather continues for some time. However, if either the mispricing becomes too large or it lasts for long enough, investors find it cost-effective or possible to seek arbitrage. The arbitrageurs will ultimately drive away any profitable opportunity from mispricing and the market values of ETN would reflect that of the asset whose performance they follow.

On the basis of the above discussion, in this article we test two simple hypotheses. The first hypothesis puts forward the suggestion that there exists a long-run relationship between an ETN market and the underlying asset whose performance it is tracking. It is, however, possible that the direct relationship between the markets in question might not always be linear. The existence of various frictions may lead to a nonlinear adjustment between the prices in these markets, which leads us to our second hypothesis. The second hypothesis postulates that the long-run adjustment process between the underlying assets and the ETN would be nonlinear. Together, these two hypotheses suggest that despite the possible existence of nonlinearity, the value of ETP would reflect the value of its underlying assets. In other words, market prices of the ETN would be cointegrated with the value of their underlying assets.

DATA AND METHODOLOGY

The data

This article uses daily market closing prices of 19 iPath ETN, issued by the Barclays Bank PLC that closely tracks performances of 19 different commodity indexes issued by DJ-UBS, known as DJ-UBS commodity indexes¹⁰. The DJ-UBS data are obtained from the Dow-Jones Website (www.djindexes.com/investable-products/?assetclass=alternativeassetclass) and the ETN daily closing prices data are from Compustat¹¹. The data span the period from 2 January 2009 to 31 December 2011 and are transformed into natural logarithms before estimation. We do not use the daily indicative value of ETN,

counterpart of Net Asset Value of ETF, because of their *nearly* mathematical relationship with the underlying index value. All ETN indicative values almost perfectly match the value of the underlying index. However, the market prices of ETN may significantly differ from the indicative values, or the underlying index value, as they are determined by a number of factors including investors' and issuers' characteristics (Wright *et al*, 2010; Diavatopoulos *et al*, 2011).

Table 1 presents the symbols of the ETN in our sample and those of their underlying assets. In order to carry out a comparable analysis, we select ETN issued by Barclays Capital under the trading name of iPath. All of these ETN have the same expense ratio of 0.75 per cent and future

Table 1: ETN and their underlying assets

ETN Ticker	Underlying asset symbol	Sector	Focus	Inception date	Market capitalization
DJP	DJUBSTR	Broad market	Broad market	6 June 2006	\$2 143 811 198
JJA	DJUBAGTR	Agriculture	Whole sector	23 October 2007	\$112 547 806
JJU	DJUBALTR	Industrial metals	Aluminum	24 June 2008	\$3 798 620
NIB	DJUBCCTR	Agriculture	Cocoa	24 June 2008	\$24 470 927
JO	DJUBKCTR	Agriculture	Coffee	24 June 2008	\$29 015 989
JJC	DJUBHGTR	Industrial metals	Copper	23 October 2007	\$125 116 203
BAL	DJUBCTTR	Agriculture	Cotton	24 June 2008	\$31 192 876
JJE	DJUBENTR	Energy	Whole sector	23 October 2007	\$13 433 061
JJG	DJUBGRTR	Agriculture	Grains	23 October 2007	\$153 368 489
JJM	DJUBINTR	Industrial metals	Whole sector	23 October 2007	\$39 329 600
LD	DJUBPBTR	Industrial metals	Lead	24 June 2008	\$1 594 010
COW	DJUBLITR	Livestock	Whole sector	23 October 2007	\$53 173 366
GAZ	DJUBNGTR	Energy	Natural gas	23 October 2007	\$38 054 112
JJN	DJUBNITR	Industrial metals	Nickel	23 October 2007	\$7 311 348
PGM	DJUBPLTR	Precious metals	Platinum	24 June 2008	\$31 922 620
JJP	DJUBPRTR	Precious metals	Whole sector	24 June 2008	\$38 977 530
JJS	DJUBSOTR	Agriculture	Softs	24 June 2008	\$13 932 968
SGG	DJUBSBTR	Agriculture	Sugar	24 June 2008	\$24 877 568
JJT	DJUBSNTR	Industrial metals	Tin	24 June 2008	\$14 193 783

Notes: Typical maturity of commodity ETN is 30 years from inception. Market capitalization as of 18 May 2012.

execution cost of 0.10 per cent and track different DJ-UBS commodity indexes: broad market, sectors and single commodities. The table also gives the inception dates of the notes, which normally mature in 30 years. The last column of the table shows the market capitalization of ETN, which vary among themselves.

The methodology

Consider the following econometric model that specifies the long-run relationship between a particular ETN and the underlying commodity index,

$$ETN_t = \alpha + \beta CFI_t + u_t \quad (1)$$

where ETN is one of the ETN whose performance is tied to the underlying broad market commodity futures index, CFI is the independent variable (that is, DJ-UBS Commodity Index), u is the error term and t is the time index. The presence of a cointegrating relationship between the right- and left-hand side variables can be tested using the Engle and Granger (1987) two-step methodology. In the first step, the time series properties of the cointegrating variables are examined, and the properties of the residual series obtained from the long-run regression, $\hat{u}_t$, are examined in the second step. The focus of this article is on the residual term or the error correction term (ECT). In particular, the long-run adjustment process, represented by this ECT, between an ETN and its benchmark asset can be linear or nonlinear over time.

Linear adjustment: The EG test

Assuming that the variables ETN and CFI are integrated of Order 1, that is, $I(1)$, consider

the simplest way to model the temporal behavior of $\hat{u}_t$, the residual from the cointegrating regression of equation (1) as shown below,

$$\Delta \hat{u}_t = \rho \hat{u}_{t-1} + \varepsilon_t \quad (2)$$

where $\varepsilon \sim i.i.d.$ In order to ensure that the residual series converges to its long-run value, the value of ρ should be in the range of $(-2, 0)$. This is equivalent to the traditional Dickey-Fuller stationarity test. Adding some lagged values of the left-hand side variable will account for any series correlation in the data resulting in the Augmented Dickey-Fuller (ADF) specification. Other than the widely cited poor power problem of the ADF type test, equation (2) assumes that the long adjustment process is linear and symmetric. If the actual series is nonlinear in nature, any test of long-run convergence based on equation (2) will be mis-specified (Pippenger and Goering, 1993). A natural departure from the above specification must start with a formal investigation if the $\hat{u}_t$ series is associated with the existence of nonlinearity.

Testing nonlinearity: The Harvey-Leybourne linearity test¹²

In order to introduce nonlinearity in the data generation process, equation (2) can be reformulated with a transition function on the right-hand side such that we get the following equation,

$$\Delta \hat{u}_t = \rho \hat{u}_{t-1} + f(\hat{u}_{t-d}, \theta) \hat{u}_{t-1} + \varepsilon_t \quad (3)$$

where $f(\hat{u}_{t-d}, \theta)$ is the transition function (d is the delay parameter), which denotes a particular nonlinear, symmetric (ESTAR) or asymmetric (LSTAR) process and ε_t is a white noise process.

Harvey and Leybourne (2007) reparameterized the transition function above through second-order Taylor series expansion and obtained the following auxiliary regression equation, which assumes that the underlying series is stationary:

$$\hat{u}_t = \beta_0 + \beta_1 \hat{u}_{t-1} + \beta_2 \hat{u}_{t-1}^2 + \beta_3 \hat{u}_{t-1}^3 + \sum_{j=1}^p \beta_{4,j} \Delta \hat{u}_{t-j} + \varepsilon_t \quad (4)$$

Equation (4) forms the basis of the linearity test where the null and alternative hypotheses of linearity can be specified as

$$H_0 : \beta_2 = \beta_3 = 0$$

$$H_1 : \text{at least one of } \beta_2, \beta_3 \neq 0$$

The hypothesis testing can be carried out using the Wald statistic

$$W_1 = \frac{RSS_1 - RSS_0}{RSS_0/T} \sim \chi^2(2)$$

where RSS_0 denotes the residual sum of squares from the unrestricted model and RSS_1 is obtained from the restricted version of these equations under the null. The critical values of the W_0 statistic are taken from $\chi^2(2)$ distribution. If one is sure about the integration properties of the data, and it is known beforehand that the series are integrated of Order 1, that is, $I(1)$, then equation (4) will be changed as follows,

$$\hat{u}_t = \beta_0 + \beta_1 (\Delta \hat{u}_{t-1}) + \beta_2 (\Delta \hat{u}_{t-1})^2 + \beta_3 (\Delta \hat{u}_{t-1})^3 + \sum_{j=2}^p \beta_{4,j} \Delta \hat{u}_{t-j} + \varepsilon_t \quad (5)$$

where variables are as defined before. The null and alternative hypotheses remain the same and the test statistic is now given as follows,

$$W_2 = \frac{RSS_1 - RSS_0}{RSS_0/T} \sim \chi^2(2)$$

which follows χ^2 distribution with two degrees of freedom. A more general framework for the test can be developed by combining equations 4 and 5 as follows:

$$\hat{u}_t = \beta_0 + \beta_1 \hat{u}_{t-1} + \beta_2 \hat{u}_{t-1}^2 + \beta_3 \hat{u}_{t-1}^3 + \beta_5 (\Delta \hat{u}_{t-1})^2 + \beta_6 (\Delta \hat{u}_{t-1})^3 + \sum_{j=1}^p \beta_{4,j} \Delta \hat{u}_{t-j} + \varepsilon_t \quad (6)$$

The null and alternative hypotheses of linearity, whether $\hat{u}_t$ is $I(0)$ or $I(1)$, based on equations (6) can be specified as

$$H_0: \beta_2 = \beta_3 = \beta_5 = \beta_6 = 0$$

$$H_1: \text{at least one of } \beta_2, \beta_3, \beta_5, \beta_6 \neq 0$$

The hypothesis testing can be carried out using the Wald statistic

$$W_3 = \frac{RSS_1 - RSS_0}{RSS_0/T} \sim \chi^2(4)$$

which follows χ^2 distribution with four degrees of freedom.

Nonlinear adjustment: The KSS (2003) nonlinear EG test

Once the error correction series are tested for the presence of nonlinear dynamics, the next step is to apply a unit root test that is able to detect stationarity in a nonlinear time series. We choose to apply the test proposed by Kapetanios, Shin and Snell (2003) (KSS for short) who broaden the familiar ADF test to detect nonstationarity in a nonlinear time series. They keep the null hypothesis of nonstationarity as in the ADF test, but the alternative hypothesis is now that the series is a nonlinear but globally stationary process.

The KSS test is based on a univariate exponential smooth transition autoregressive of

Order 1, ESTAR(1) process and the empirical specification results in the following auxiliary regression

$$\Delta \hat{u}_t = \delta \hat{u}_{t-1}^3 + \sum_{j=1}^p \lambda_j \Delta \hat{u}_{t-j} + \varepsilon_t \quad (7)$$

where the lagged terms are included to account for possible presence of serial correlation in the error terms. The null hypothesis of nonstationarity is now that $H_0: \delta = 0$ against the alternative of stationarity is $H_1: \delta < 0$. Kapetanios *et al* (2003) recognize that the test statistic does not have an asymptotic standard normal distribution, and therefore provide the critical values on page 364 of their paper.

Nonlinear adjustment: The KSS (2006) cointegration test

If the stationarity is confirmed using the nonlinear unit root test in the previous step, we proceed to specify the nonlinear error correction model following Kapetanios *et al* (2006)¹³. This specification has two advantages over the procedures outlined above. First, it will allow us to directly test the existence of nonlinear cointegration between the market values of an ETN and its underlying benchmark. Second, it will also give us an estimate of the speed of the error correction in the values of an ETN toward its benchmark value.

Following Kapetanios *et al* (2006), we can write the empirical specification of the nonlinear error correction model¹⁴,

$$\Delta ETN_t = \rho \hat{u}_{t-1}^3 + \beta \Delta CFI_t + u_t \quad (8)$$

where the variables are as defined before. The null hypothesis of no cointegration is now that

$H_0: \rho = 0$ against the alternative of nonlinear ESTAR cointegration of $H_1: \rho < 0$.

RESULTS AND ANALYSIS

This section presents the empirical results and also offers some explanations for the findings. The descriptive statistics of the data are presented in Table 2. As can be seen from Table 2, the prices of the underlying assets, that is, the value of a commodity futures index, are much higher than that of the ETN assets. This reflects the fact that ETN are created in smaller units or shares for ease of intraday trading. In addition, this has created an opportunity for small investors to gain exposure in the commodity futures markets. Another thing to note is that in general sample standard deviation of ETN prices is smaller than those of commodity indexes.

Next, the risk-return tradeoff facing these notes is analyzed. The only priced factor that is considered here is excess returns on the underlying index. Therefore, excess returns on the notes are regressed on the excess returns on the benchmarks that the notes are based on. In this time series regression, the model adequacy is tested by setting the intercept equal to 0 and the β equal to 1 – resulting in an F -test. The estimation results and the test statistics are reported in Table 3. Several observations can be made based on the results. First, the one-factor model seems adequate for capturing the risk return tradeoff of these notes as the time series regressions produce an insignificant intercept term (that is, α) for 15 out of 19 notes and high R^2 for all of them. The notes for which intercept terms are significant earn negative excess returns arising, possibly, due to the existence of fees and other related trading costs. Second, the F -test cannot reject the null

Table 2: Descriptive statistics

<i>ETN</i>					<i>DJUBS underlying assets</i>				
<i>Symbol</i>	<i>Mean</i>	<i>SD</i>	<i>Skew</i>	<i>E.K.</i>	<i>Symbol</i>	<i>Mean</i>	<i>SD</i>	<i>Skew</i>	<i>E.K.</i>
DJP	41.91	5.32	0.13	-0.83	DJUBSTR	278.80	35.65	0.10	-0.88
JJA	49.20	9.68	0.47	-1.30	DJUBAGTR	142.56	28.22	0.45	-1.34
JJU	28.82	4.11	-0.41	-0.70	DJUBALTR	100.45	14.58	-0.47	-0.60
NIB	42.53	4.60	-0.33	0.58	DJUBCCTR	74.23	7.80	-0.30	0.45
JO	49.57	13.36	0.54	-1.15	DJUBKCTR	65.68	17.83	0.52	-1.18
JJC	43.91	10.32	-0.52	-0.36	DJUBHGTR	715.28	168.78	-0.52	-0.37
BAL	50.78	22.13	0.91	-0.22	DJUBCTTR	48.18	20.92	0.87	-0.30
JJE	23.29	2.18	0.13	-0.52	DJUBENTR	234.62	20.31	0.16	-0.55
JJG	43.27	6.78	0.41	-1.11	DJUBGRTR	106.08	16.67	0.41	-1.15
JJM	37.32	7.24	-0.62	-0.34	DJUBINTR	325.27	63.19	-0.64	-0.34
LD	53.70	10.32	-0.72	-0.29	DJUBPBTR	443.69	85.14	-0.74	-0.24
COW	29.71	1.45	0.08	-0.12	DJUBLITR	72.77	3.56	-0.11	-0.34
GAZ	11.49	5.19	1.01	0.78	DJUBNGTR	8.69	3.78	1.07	0.87
JJN	29.34	6.85	-0.35	-0.44	DJUBNITR	450.66	104.78	-0.38	-0.43
PGM	36.29	5.58	-0.66	-0.67	DJUBPLTR	821.14	128.57	-0.60	-0.72
JJP	68.85	17.56	0.41	-1.08	DJUBPRTR	388.30	100.24	0.40	-1.10
JJS	58.79	18.10	0.37	-1.40	DJUBSOTR	142.36	43.98	0.35	-1.42
SGG	68.77	18.83	0.05	-1.31	DJUBSBTR	389.49	107.35	0.05	-1.32
JJT	46.57	14.71	0.36	-0.87	DJUBSNTR	683.27	215.09	0.32	-0.91

Notes: The descriptive statistics of the daily closing market prices and the daily values of their underlying assets are presented in this table. SD, Skew and E.K. stand for standard deviation, skewness and excess kurtosis, respectively.

Table 3: Risk-return tradeoff for ETN

<i>Dependent variable</i>	<i>Independent variable</i>	α	β	<i>F-test</i>	R^2
DJP	DJUBSTR	-0.0001 (0.693)	0.999 (0.000)	0.820 (0.921)	0.996
JJA	DJUBAGTR	0.0001 (0.688)	1.002 (0.000)	0.222 (0.801)	0.995
JJU	DJUBALTR	-0.0009 (0.206)	0.989 (0.000)	1.155 (0.315)	0.962
NIB	DJUBCCTR	-0.0004 (0.382)	0.994 (0.000)	0.571 (0.565)	0.983
JO	DJUBKCTR	-0.0001 (0.799)	0.999 (0.000)	0.392 (0.961)	0.992
JJC	DJUBHGTR	-0.0006 (0.231)	0.993 (0.000)	1.047 (0.351)	0.983
BAL	DJUBCTTR	-0.0001 (0.993)	1.000 (0.000)	0.868 (0.991)	0.971
JJE	DJUBENTR	-0.0006 (0.385)	0.993 (0.000)	0.547 (0.578)	0.967
JJG	DJUBGRTR	0.0003 (0.282)	1.004 (0.000)	1.073 (0.342)	0.994
JJM	DJUBINTR	-0.0005 (0.393)	0.993 (0.000)	0.503 (0.604)	0.971
LD	DJUBPBTR	-0.0020* (0.023)	0.974 (0.000)	3.956* (0.019)	0.939
COW	DJUBLITR	-0.0010 (0.718)	0.999 (0.000)	0.872 (0.916)	0.997
GAZ	DJUBNGTR	-0.0027* (0.000)	0.969 (0.000)	9.035* (0.000)	0.961
JJN	DJUBNITR	-0.0017* (0.027)	0.978 (0.000)	3.953* (0.019)	0.955
PGM	DJUBPLTR	-0.0004 (0.403)	0.995 (0.000)	0.412 (0.662)	0.976
JJP	DJUBPRTR	-0.0009** (0.054)	0.988 (0.000)	2.781** (0.062)	0.981
JJS	DJUBSOTR	-0.001 (0.102)	0.986 (0.000)	1.979 (0.138)	0.964
SGG	DJUBSBTR	-0.0005 (0.233)	0.993 (0.000)	1.078 (0.340)	0.985
JJT	DJUBSNTR	-0.0041 (0.001)	0.949 (0.000)	8.911 (0.000)	0.892

Notes: *P*-values are reported within parentheses. *F*-test column reports that the test statistic for the joint test intercept (that is, α) is 0 and the slope coefficient (that is, β) is unity. * and ** denote rejection of the null at 5 per cent and 10 per cent level of significance, respectively.

hypothesis in 15 of 19 series. The *F*-tests are significant only when the intercept is significant. In unreported results, it is also found that all β coefficients are indistinguishable from unity. Together, this indicates that a one-factor model is generally a good description of the note's risk-return tradeoff. The results in this section are in line with the findings of Aroskar and Ogden (2012), who report that most of the ETN enjoy minimal tracking errors.

The main estimation phase of this article begins with an examination of the time series properties of our data. In particular, unit root tests are applied to all (logarithm of) ETN price series and

commodity indexes and the results are presented in Table 4. Three different types of tests are used, namely, the ADF (Dickey and Fuller, 1981) test, the KPSS test (Kwiatkowski *et al*, 1992) and the Zivot and Andrews (1992) test. The ADF test is designed with the hypothesis of nonstationarity under the null, whereas the KPSS assumes stationarity under the null. For both, test equations included a constant and a trend term. These tests do not, however, allow for structural breaks in the data. To check whether the data are stationary with breaks in the intercept or trend, Zivot and Andrews (1992) tests, or the ZA tests, are also applied, which allows structural break, both in the

Table 4: The unit root test results

<i>ETN</i>				<i>DJUBS underlying assets</i>			
<i>Ticker</i>	<i>ADF</i>	<i>KPSS</i>	<i>ZA</i>	<i>Ticker</i>	<i>ADF</i>	<i>KPSS</i>	<i>ZA</i>
DJP	-2.057	0.733*	-4.125	DJUBSTR	-2.021	0.734*	-4.112
JJA	-1.743	0.890*	-4.021	DJUBAGTR	-1.803	0.888*	-4.074
JJU	-1.255	1.411*	-3.613	DJUBALTR	-1.357	1.446*	-3.437
NIB	-1.374	1.049*	-3.297	DJUBCCTR	-1.446	1.041*	-3.312
JO	-1.997	0.996*	-3.757	DJUBKCTR	-1.750	0.994	-3.698
JJC	-1.806	1.642	-3.217	DJUBHGTR	-1.606	1.646	-2.866
BAL	-0.969	0.899	-4.162	DJUBCTTR	-0.946	0.894	-4.304
JJE	-3.955*	0.474	-5.356*	DJUBENTR	-3.683*	0.477	-4.957
JJG	-2.232	1.026	-3.850	DJUBGRTR	-2.309	1.030	-3.926
JJM	-1.233	1.705	-3.002	DJUBINTR	-1.176	1.722	-3.137
LD	-2.293	1.222	-3.521	DJUBPBTR	-1.991	1.232	-3.683
COW	-3.545*	0.790	-4.441	DJUBLITR	-3.882*	0.803	-4.489
GAZ	-3.486*	0.532	-5.720*	DJUBNGTR	-3.989*	0.657	-4.941
JJN	-1.401	1.783	-3.346	DJUBNITR	-1.453	1.789	-3.431
PGM	-1.413	1.743	-3.327	DJUBPLTR	-1.518	1.868	-3.780
JJP	2.647	0.445	-4.161	DJUBPRTR	-2.944	0.433	-4.414
JJS	-1.191	0.756	-3.738	DJUBSOTR	-0.942	0.754	-3.738
SGG	-1.865	0.475	-2.973	DJUBSBTR	-1.944	0.474	-3.140
JJT	-0.626	1.469	-4.623	DJUBSNTR	-0.298	1.453	-4.660

Notes: For the ADF test, the lag length is selected using testing down method from a maximum lag of 8. For the KPSS (Kwiatkowski *et al*, 1992) test, the lag truncation parameter equals the integer part of $4(T/100)^{1/4}$. The lag length for the ZA (Zivot and Andrews, 1992) is selected via *t*-test. * denotes rejection of the null at 5 per cent level of significance. Critical values for ADF are from MacKinnon (1996) and for KPSS and ZA tests from the papers cited earlier.

mean and the trend, with the nonstationarity under the null hypothesis. As can be seen from the results presented in Table 4, though there are some inconclusive cases where three different tests produce some conflicting results, the overall results indicate that the data are mostly nonstationary and contain a unit root.

The next step is to examine whether each pair of time series representing market values has a common trend over the long run. Table 5 documents the long-run cointegrating regression results. This long-run cointegrating regression is the basis of the second of the two steps in the EG procedure. The regression is run based on equation (1) in the previous section. All coefficients, both intercepts and slopes, in the cointegrating regressions are statistically significant.

The EG–ADF tests are applied to the residual series of the cointegrating relationship and the results are presented in the last column of Table 5. We cannot reject the null hypothesis of no cointegration in 8 pairs of markets and can reject it in the other 11 cases. This may indicate that most of the market value series do not exhibit a common trend over time. However, a number of authors have mentioned that if a series displays nonlinearity, the linear unit root tests are largely mis-specified (Kapetanios *et al*, 2003; Pippenger and Goering, 1993). It is therefore instructive to test these series for possible presence of nonlinearity in their data-generating process before one can make conclusions about the long-run relationship between prices of ETN and their underlying values.

As postulated earlier, we expect that the adjustment process between any two markets would exhibit some degree of nonlinearity. The possible reasons for such nonlinearity include the existence of heterogeneous cost structure, investors' heterogeneity, investors'

Table 5: EG tests

<i>Dependent variable</i>	<i>Independent variable</i>	δ_0	δ_1	<i>ADF–EG</i>
DJP	DJUBSTR	–1.843	0.991	–2.971
JJA	DJUBAGTR	–1.023	0.992	–1.960
JJU	DJUBALTR	–1.125	0.973	–3.968*
NIB	DJUBCCTR	–0.683	1.029	–2.994
JO	DJUBKCTR	–0.241	0.991	3.305**
JJC	DJUBHGTR	–2.756	0.995	–3.104**
BAL	DJUBCTTR	0.059	0.998	–3.589*
JJE	DJUBENTR	–2.729	1.077	–4.911*
JJG	DJUBGRTR	–0.881	0.997	–2.156
JJM	DJUBINTR	–2.138	0.995	–2.526
LD	DJUBPBTR	–2.093	0.997	–5.941*
COW	DJUBLITR	–0.835	0.986	–1.689
GAZ	DJUBNGTR	0.149	1.059	–2.717
JJN	DJUBNITR	–2.737	1.001	–3.324**
PGM	DJUBPLTR	–2.896	0.967	–2.587
JJP	DJUBPRTR	–1.648	0.986	–6.960*
JJS	DJUBSOTR	–0.851	0.993	–10.725*
SGG	DJUBSBTR	–1.691	0.993	–4.376*
JJT	DJUBSNTR	–2.657	0.995	–7.001*

Notes: The long-run cointegrating relationship is estimated with a constant, α , and the underlying asset, that is, the commodity futures index, as an independent variable with estimated coefficient being equal to β . The *P*-values for EG–ADF tests are taken from MacKinnon (1996). * and ** denote rejection of the null at 5 per cent and 10 per cent level of significance, respectively.

behavioral issues including momentum and disposition strategies (McMillan and Speight, 2006), and the process of share or unit creation and redemption in ETF and ETN products.

To this end, we apply three different versions of the Harvey and Leybourne (2007) tests with test statistics labeled as W_1 , W_2 and W_3 , respectively. The linearity test results are shown in Table 6. All error correction series except for three cases are

Table 6: Linearity test results

<i>Markets</i>	W_1	W_2	W_3	<i>Decision</i>
DJP–DJUBSTR	5.426 [0.066]	14.628 [0.000]	11.333 [0.023]	Nonlinear
JJA–DJUBAGTR	4.521 [0.104]	1.543 [0.462]	4.810 [0.307]	Linear
JJU–DJUBALTR	15.255 [0.000]	0.169 [0.918]	19.884 [0.000]	Nonlinear
NIB–DJUBCCTR	4.113 [0.127]	7.841 [0.019]	8.900 [0.064]	Nonlinear
JO–DJUBKCTR	0.673 [0.714]	0.402 [0.818]	3.421 [0.489]	Linear
JJC–DJUBHGTR	2.088 [0.352]	15.806 [0.000]	11.903 [0.018]	Nonlinear
BAL–DJUBCTTR	44.513 [0.000]	5.246 [0.072]	68.031 [0.000]	Nonlinear
JJE–DJUBENTR	16.495 [0.000]	10.443 [0.005]	22.563 [0.000]	Nonlinear
JJG–DJUBGRTR	14.272 [0.001]	0.221 [0.895]	17.080 [0.002]	Nonlinear
JJM–DJUBINTR	60.874 [0.000]	14.937 [0.000]	61.185 [0.000]	Nonlinear
LD–DJUBPBTR	5.389 [0.067]	23.729 [0.000]	27.680 [0.000]	Nonlinear
COW–DJUBLITR	4.998 [0.082]	0.132 [0.993]	8.548 [0.073]	Nonlinear
GAZ–DJUBNGTR	5.010 [0.081]	200.803 [0.000]	21.836 [0.000]	Nonlinear
JJN–DJUBNITR	2.626 [0.269]	0.968 [0.616]	6.128 [0.189]	Linear
PGM–DJUBPLTR	51.758 [0.000]	210.454 [0.000]	110.728 [0.000]	Nonlinear
JJP–DJUBPRTR	24.756 [0.000]	43.476 [0.000]	45.042 [0.000]	Nonlinear
JJS–DJUBSOTR	6.360 [0.042]	2.660 [0.264]	10.024 [0.040]	Nonlinear
SGG–DJUBSBTR	7.417 [0.024]	16.468 [0.000]	15.805 [0.003]	Nonlinear
JJT–DJUBSNTR	6.701 [0.035]	3.692 [0.157]	8.116 [0.087]	Nonlinear

Notes: The above test statistics are for the null of linearity against the alternative of nonlinearity. The relevant $\chi^2(2)$ 5 per cent and 10 per cent critical value is 5.99 and 4.61, respectively. Optimal lag length is selected using the general to specific approach from maximum lag of 4. *P*-values are reported up to 3 decimal places. *P*-values are reported within brackets.

nonlinear. These findings largely support our hypothesis that the adjustment process between the market values of an ETN and its underlying asset would exhibit nonlinearity.

Having found that 16 out of 19 adjustment processes are nonlinear, we apply unit root tests that assume that the underlying time series is nonlinear as outlined in the previous section. Two versions of the KSS tests are applied here. Following the procedure proposed in Kapetanios *et al* (2003), we develop a demeaned and a detrended series before applying the tests. The results of the Kapetanios *et al* (2003) test are

reported in Table 7. The test statistics reported under t_{DM} and t_{DT} correspond to the demeaned and the detrended series, respectively. As can be seen from the table, in all but three cases, the null of nonstationarity is rejected. This lends some support for the hypothesis that postulates nonlinear mean reversion in the adjustment process between the market value of an ETN and that of a commodity futures index.

The Kapetanios *et al* (2006) test of nonlinear cointegration results is reported in Table 8. The nonlinear cointegration tests are based on equation (8). The table reports two different

Table 7: Nonlinear unit root tests

Market	Sector/Commodity	t_{DM}	t_{DT}	Decision
DJP-DJUBSTR	Broad market	-2.260	-2.670	Nonstationary
JJA-DJUBAGTR	Agriculture	-3.341*	-3.491*	Stationary
JJU-DJUBALTR	Aluminum	-6.260*	-7.441*	Stationary
NIB-DJUBCCTR	Cocoa	-3.639*	-3.475*	Stationary
JO-DJUBKCTR	Coffee	-3.538*	-3.708*	Stationary
JJC-DJUBHGTR	Copper	-2.457	-3.547*	Stationary
BAL-DJUBCTTR	Cotton	-8.341*	-8.124*	Stationary
JJE-DJUBENTR	Energy	-4.306*	-5.174*	Stationary
JJG-DJUBGRTR	Grains	-4.535*	-4.431*	Stationary
JJM-DJUBINTR	Industrial metals	-5.849*	-3.785*	Stationary
LD-DJUBPBTR	Lead	-0.223	0.002	Nonstationary
COW-DJUBLITR	Livestock	-3.404*	-5.692*	Stationary
GAZ-DJUBNGTR	Natural gas	-3.825*	-3.779*	Stationary
JJN-DJUBNTR	Nickel	-2.245	-2.688	Nonstationary
PGM-DJUBPLTR	Platinum	-3.313*	-3.363**	Stationary
JJP-DJUBPRTR	Precious metals	-2.820**	-2.887	Stationary
JJS-DJUBSOTR	Softs	-6.248*	-6.624*	Stationary
SGG-DJUBSBTR	Sugar	-4.726*	-5.088*	Stationary
JJT-DJUBSNTR	Tin	-5.681*	-5.927*	Stationary

Notes: t_{DM} and t_{DT} refer to the nonlinear test statistic proposed by Kapetanios *et al* (2003) with demeaned and detrended data, respectively. The relevant critical values are given therein. Optimal lag length is selected using testing down approach from the maximum lag length of 8. * and ** denote rejection of the null at 5 per cent and 10 per cent level of significance, respectively.

t -statistics for the null of no cointegration, first using demeaned data series and then using demeaned and detrended data series¹⁵. As can be seen, all of the notes are found to be cointegrated with their underlying benchmark. Given that the Kapetanios *et al* (2006) test of nonlinear cointegration is more powerful than the Kapetanios *et al* (2003) nonlinear EG test, we can rely on the results from the former testing framework, which also give us stronger results.

In brief, we find that commodity ETN markets mostly reflect the value of the assets that they track as underlying assets. The process of

price adjustment between the notes and the underlying assets is, however, nonlinear. Possible reasons for cointegration found include rational expectation, economic linkage and improved trading platform. On the other hand, possible reasons for absence of linear cointegration found in this article may include presence of heterogeneous investors with different motives (McMillan and Speight, 2006), a complex process of share or unit creation and redemption of ETF and ETN (Wright *et al*, 2010), limits of arbitrage among these markets, and active management of the fund toward achieving high returns.

Table 8: Nonlinear cointegration tests

<i>Market</i>	<i>Sector/Commodity</i>	t_{ECM-DM}	t_{ECM-DT}	<i>Decision</i>
DJP–DJUBSTR	Broad market	–10.11*	–10.21*	Cointegrated
JJA–DJUBAGTR	Agriculture	–13.03*	–12.86*	Cointegrated
JJU–DJUBALTR	Aluminum	–13.23*	–13.42*	Cointegrated
NIB–DJUBCCTR	Cocoa	–11.40*	–11.51*	Cointegrated
JO–DJUBKCTR	Coffee	–11.37*	–14.61*	Cointegrated
JJC–DJUBHGTR	Copper	–11.02*	–13.45*	Cointegrated
BAL–DJUBCTTR	Cotton	–16.20*	–17.71*	Cointegrated
JJE–DJUBENTR	Energy	–12.13*	–14.25*	Cointegrated
JJG–DJUBGRTR	Grains	–15.15*	–14.14*	Cointegrated
JJM–DJUBINTR	Industrial metals	–15.60*	–15.85*	Cointegrated
LD–DJUBPBTR	Lead	–7.78*	–7.70*	Cointegrated
COW–DJUBLITR	Livestock	–8.91*	–15.03*	Cointegrated
GAZ–DJUBNGTR	Natural gas	–4.96*	–4.49*	Cointegrated
JJN–DJUBNITR	Nickel	–9.93*	–12.59*	Cointegrated
PGM–DJUBPLTR	Platinum	–4.32*	–4.41*	Cointegrated
JJP–DJUBPRTR	Precious metals	–7.53*	–7.80*	Cointegrated
JJS–DJUBSOTR	Softs	–13.06*	–13.17*	Cointegrated
SGG–DJUBSBTR	Sugar	–11.11*	–11.21*	Cointegrated
JJT–DJUBSNTR	Tin	–10.88*	–10.54*	Cointegrated

Notes: t_{ECM-DM} and t_{ECM-DT} refer to the nonlinear cointegration test statistic proposed by Kapetanios *et al* (2006) with demeaned and detrended data, respectively. The relevant critical values are given therein. * and ** denote rejection of the null at 5 per cent and 10 per cent level of significance, respectively. Optimal lag length is selected using testing down approach from the maximum lag length of 8.

CONCLUDING REMARKS

An exposure to commodity prices can be obtained in a number of ways. An alternative to taking position in commodity futures is to invest in ETP that are linked to the performance of some commodity futures indexes. These ETP include equity-like ETF and debt-like ETN. These financial products are traded continuously on some exchanges, for example, the NYSE Acra. The objective of this article is to examine the nature of long-run relationship between samples of ETN and commodity futures indexes as their

underlying assets. In addition, the nature of adjustment among these assets is also investigated. It is hypothesized that the adjustment process would exhibit some nonlinearity that creates a band of inertia in the short run causing some degree of mispricing. In the long run, however, this mispricing should go away and the long-run relationship should be established.

The hypotheses are tested, first, within the EG cointegration framework that allows nonlinear mean reversion in the error correction series. Then, formal tests of linearity are applied along

with linear and nonlinear unit root tests. Finally, a test of nonlinear cointegration is also applied that shows that all the price series of the notes are cointegrated with their underlying benchmark assets. The results are mostly supportive of two hypotheses proposed in the article. More particularly, there exists a long-run relationship between the market price of an ETN and the value of the underlying commodity index that the ETN is tracking. The existence of such a long-run relationship indicates that ETP are generally able to do a good job of tracking the performance of some underlying financial assets. This is reflected in the close common trend in the prices of the ETN and their underlying assets. Second, the adjustment process between the prices of these two different types of assets may not always be linear due to a number of reasons put forward in the article. Rather, the adjustment processes exhibits mostly nonlinearity.

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NOTES

- 1 Estimation by CFTC (2008) puts this figure at over \$160 billion.
- 2 Another widely known ETP is ETF, which is an equity product.
- 3 For example, Richie *et al* (2008) use the cost of carry model to study the link between the

S&P 500 futures market and the SPDR (ETF) as spot market.

- 4 The rational expectation hypothesis was originally proposed by Muth (1961) and has since been applied in many related areas including efficient market hypothesis of capital markets.
- 5 For a detailed introduction to ETNs, see Wright *et al* (2010).
- 6 See Dwyer *et al* (1996) and McMillan and Speight (2002, 2006) for details on the possibility of nonlinearity in the adjustment among financial markets.
- 7 Typically, traders in the ETN market buy and sell in blocks of 25 000 or 50 000 units (Wright *et al*, 2010).
- 8 These reasons may hold true for other markets. Our focus in this article is on commodity markets only.
- 9 See Diavatopoulos *et al* (2011) for a detailed discussion on this issue.
- 10 The iPath has 19 ETN as part of the DJ-UBS Commodity Index Total Return^{TM} Series that have exposure to front month commodities futures contracts.
- 11 Extracted through Wharton Research Data Services.
- 12 For a complete discussion on the test, interested readers are referred to Harvey and Leybourne (2007).
- 13 The motivation for this section rests on a reviewer's suggestion, which is gratefully acknowledged.
- 14 This specification is obtained from a Taylor series expansion that involves a nonlinear ESTAR process.
- 15 The results on raw data series are similar and hence have not been reported to conserve space.

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