Energy Economics 52 (2015) 240–245

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

Testing fractional persistence and non-linearities in the natural gas market: An application of non-linear deterministic terms based on Chebyshev polynomials in time☆

OlaOluwa Simon Yaya [a], Luis Alberiko Gil-Alana [b,*], Hector Carcel [b]

[a] Department of Statistics, University of Ibadan, Nigeria
[b] Faculty of Economics, University of Navarra, Pamplona, Spain

ARTICLE INFO

Article history:
Received 7 September 2015
Received in revised form 14 October 2015
Accepted 18 October 2015
Available online 30 October 2015

JEL classification:
C22
L95
N70

Keywords:
Fractional integration
Chebyshev polynomial
Natural gas
Non-linearity

ABSTRACT

Studying variations of natural gas prices in relation to consumer prices may give us better indicators for the analysis of economic activity. This paper deals with the analysis of natural gas spot prices using fractional integration techniques in the context of non-linear deterministic trends. We find nonstationarity with mean reverting coefficients (i.e., orders of integration in the range (0.5, 1)) in the daily and monthly series, as well as in their logarithmic transformations. Evidences of non-linearities are only obtained in the monthly series which may be a consequence of the higher degree of volatility associated with this frequency.

1. Introduction

There are a large number of papers in the literature which test for a unit root in spot and future energy prices (Barros et al., 2014; Elder and Serletis, 2008; Ghoshray and Johnson, 2010; Maslyuk and Smyth, 2008; Ozdemir et al., 2013; Presno et al., 2014; Sadorsky, 1999; Serletis, 1992). Some of these studies have concluded that spot and/or future energy prices are nonstationary or persistent or have found mixed evidence that spot and future prices are a combination of stationarity and nonstationary processes (Pindyck, 1999; Presno et al., 2014). On the other hand, other studies have concluded that spot and/or future energy prices are stationary (Lee et al., 2006; Lee and Lee, 2009).

The issue of whether spot and future energy prices contain a unit root has several important implications for forecasting and the transmission of non-stationarities throughout the economy. Knowing the nature of gas prices time series can also be essential information for investors who wish to obtain profits from their predictions. Thus having valuable knowledge regarding the stationarity and long memory features of these series can be of great importance for them. When testing for a unit root in spot and future prices, researchers typically employ high frequency data (such as daily or weekly data) with the intention of capturing the inherent time series properties. In this paper, however, we focus not only on daily but also on monthly data of the natural gas spot prices. It is within this context that we decide to analyze the dynamics in the daily and monthly spot prices of natural gas using fractional integration techniques based on a non-linear deterministic setup with Chebyshev polynomials as the non-linear component.

Creamer and Creamer (2014) examined the daily time series of one month forward futures log-prices of natural gas from the New York Mercantile Exchange (NYMEX), testing for the existence of unit roots, and found that the null hypothesis of a unit root could not be rejected, implying nonstationarity of gas prices. The authors further applied Brownian Distance Correlation (BDC) tests in testing for non-linearity in the series and observed significant non-linear relationships. This non-linearity is linked to the fact that commodity prices are mostly determined by international market and political forces. Matilla-Garcia (2007) studied the non-linear and chaotic nature of natural gas prices using the generalized BDS and Kaplan's tests and observed strong evidence of these two properties. Kyrtsou et al. (2009) carried out numerous univariate tests

☆ The second named author acknowledges financial support from the Ministry of Education of Spain (ECO2014-55236 ECON Y FINANZAS, Spain). Comments from the Editor and two anonymous referees are gratefully acknowledged.

* Corresponding author. University of Navarra, Faculty of Economics and NICD, Edificio Amigos, E-31080 Pamplona, Spain. Tel.: +34 948 425 625; fax: +34 948 425 626.
E-mail addresses: os.yaya@ui.edu.ng (O.S. Yaya), alana@unav.es (L.A. Gil-Alana), hcarcel@alumni.unav.es (H. Carcel).

http://dx.doi.org/10.1016/j.eneco.2015.10.011
0140-9883/

for non-linearity and chaotic structure using natural gas and other energy prices and observed significant non-linearity in the dynamics of the prices. Nick and Tischler (2014) suspected non-linearity in the US and UK natural gas prices and applied a non-linear threshold cointegration approach for testing both the convergence and a long run equilibrium relationship between the two time series.

The dynamics of most economic and financial time series are often found to be non-linear and analysts employ different non-linear methodologies in order to investigate such features. The specification and estimation of time series data in Box et al. (1994) is based on the assumption of linearity, however this may turn out to be inappropriate in the empirical modeling of some series. The main non-linearity tests are the QML test (McLeod and Li, 1983); the Tsay F-test (Keenan, 1985; Tsay, 1986); the BDS test (Brock et al., 1996); the Wald-type test (Vogelsang, 1998); (Harvey and Leybourne, 2005) and the D_m-test (Peña and Rodríguez, 2006). These tests are model-based in the sense that they are based on the residuals from a linear fit and acceptance of independency in these residuals implies linearity. We believe it is therefore necessary to have a test examining non-linearities in the series without going through the rigors of estimating model parameters and generating the dependent residuals.

In the classical I(0)/I(1) world, the Augmented Dickey Fuller test (ADF, Dickey and Fuller, 1979) loses its power when facing non-linearities since its development is based on linearity. More robust tests dealing with non-linearity have therefore been developed by Kapetanios et al. (2003), Sollis (2004), Kruse (2007), Pascalau (2007) and Cuestas and Regis (2010) among others. However the most applied test is the one by KSS (2003). The limiting distribution of the KSS test is developed based on extensive Monte Carlo simulation and the test is found to perform better than the Dickey–Fuller (DF) test. Cuestas and Gil-Alana (2015) proposed a non-linearity test which tests for possibly fractional orders of integration of the series under the assumption of non-linearity in the deterministic component. The test is based on Chebyshev polynomials in time and is based on an extension of the parametric tests of Robinson (1994) for fractional integration.[1]

Following Cuestas and Gil-Alana (2015), the inclusion of non-linear structures in the fractional integration set-up is limited in the sense that the interaction of the two structures produces a model with a non-linear structure for the coefficients, implying thus that linear methods are invalid for the estimation of the parameters (Gil Alana and Caporale, 2007). Misspecification of deterministic components could affect the test's power when testing for the order of integration of the variables (see for example Perron, 1989). Zivot and Andrews (1992), Lee and Strazicich (2003a, 2003b) and Papell and Prodan (2006) proposed unit root tests incorporating structural breaks in order to improve the test's performance. Due to the fact that changes occur smoothly rather than suddenly, structural breaks may not be a proper specification of the deterministic components; Ouliaris et al. (1989) proposed regular polynomials to approximate deterministic components in the data generation process.[2,3]

So far there have been few empirical applications of the new non-linearity test by Cuestas and Gil-Alana (2015). The test is appealing in the sense that it is robust to testing between linear persistence and non-linear persistence in a fractional integration framework. Other non-linearity tests have assumed either stationarity I(0) or nonstationarity I(1) of the series but the test applied in this paper is more general, allowing for any real value of *d* for the degree of integration of the series.

[1] Bierens (1997) and Tomasevic and Stanivuk (2009) applied the Chebyshev polynomials in the context of unit root testing, observing the possibility of approximating highly non-linear trends with rather low degree polynomials.

[2] Bierens (1997) explained that Chebyshev polynomial would be a better mathematical approximation of the time functions as a result of orthogonal boundedness based on cosine functions of time.

[3] Other non-linear approaches combined with fractional integration include among others van Dijk et al. (2002).

This paper therefore contributes to the general consensus on non-linearity of natural gas prices. Studying the variations in the price of natural gas in connection with consumer prices, might lead us to an efficient indicator of a country's economic policy (Serletis and Shahmoradi, 2005). On the other hand, to determine the correct order of integration of the series is important in the sense that it is going to tell us if shocks associated with the series are going to have a transitory or a permanent effect on it. Moreover, the estimated of the fractional differencing parameter will be biased under incorrect specification of the deterministic components of the series. Thus, it is also important to examine if non-linearities are present in the data. The remainder of the paper is structured as follows: Section 2 presents the methodological techniques involved in achieving our aim for this paper. Section 3 presents the data and empirical results, while Section 4 renders the concluding remarks.

2. Methodology

2.1. Testing for unit roots

We first conduct unit root tests by means of the classical Augmented Dickey Fuller (ADF) tests of Dickey and Fuller (1979). Despite having been successful in testing for unit roots in empirical time series econometrics, the ADF test has however very low power when the series under investigation are non-linear (DeJong et al., 1992). Macroeconomic variables often display non-linear dynamics and ADF-type tests may therefore not be sensitive enough to judge well the level of stationarity of the series. The KSS (2003) test for non-linear unit root tests will also be applied in the paper along with the ADF test in determining the level of stationarity/nonstationary of the series. The starting point in the KSS test is the same specification as in the Dickey Fuller (DF) regression model with correction for possible serial correlation defined as,

$$\Delta y_t = \sum_{j=1}^{p} \rho_j \Delta y_{t-j} + \delta_{ADF} y_{t-1} + u_t, \qquad t = 1, 2, \ldots, \tag{1}$$

Where y_t is the time series and p indicates the AR order. In this model, δ is the OLS estimate from the above regression, the ρ's are the autoregressive values and u_t is the error term assumed to be white noise. In the simplest version, ignoring the augmented component, we have

$$\Delta y_t = \delta_{KSS} y_{t-1}^3 + u_t, \qquad t = 1, 2, \ldots, \tag{2}$$

derived by approximating the truncated non-linear regression model,

$$\Delta y_t = \gamma y_{t-1}\left[1 - \exp\left(-\theta y_{t-1}^2\right)\right] + u_t, \qquad t = 1, 2, \ldots, \tag{3}$$

where γ and θ are parameters in the model and u_t is a white noise process. Both the ADF and KSS are tested using the test statistic,

$$t = \frac{\hat{\delta}}{se\left(\hat{\delta}\right)}, \tag{4}$$

where $se(\hat{\delta})$ is the standard error of $\hat{\delta}$ estimated in Eqs. (1) and (2) above. We test the null hypothesis H_o: $\delta = 0$ for unit roots against the alternative H_1: $\delta < 0$ for stationarity. Just as the ADF test, the KSS can be conducted on the three classical cases of i) no intercept in the regression model; ii) with an intercept only and iii) in the presence of both an intercept and a linear time trend. The details of the test statistic and asymptotic critical points for the ADF test are given in Dickey and Fuller (1979), Davidson and Mackinnon (1993), Hamilton (1994) and Hayashi (2000). That of the KSS test can be found in Kapetanios et al. (2003).