Mean Reversion And Revenue Forecasting In A Mono Product Nigeria

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For many years, Nigerian policymakers had been unsuccessful in their attempts to manage the national economy to deal with macroeconomic instability. They have been accused of mismanagement and incompetence when it comes to preparation and execution of national budgets. In line with recent reform efforts, policymakers began to formally forecast revenue based on the benchmark price for crude oil. This paper explores the presence of long memory in oil price series. If oil price series possess long memory, then a better modeling approach will be based on autoregressive fractionally integrated moving average (ARFIMA) rather than the current ARMA model. The results of the detrended fluctuation analysis (DFA) suggest Nigeria's oil price series is anti-persistent. A Hurst exponent of 0.48 is indicative of a time series that is covariance stationary but mean-reverting.

INTRODUCTION

Nigeria is a mono product economy because oil accounts for over 95 percent of its export earnings. Moreover, about 70 percent of government revenue is derived from oil and over 90 percent of new investments are associated with oil and allied products (Ayadi and Boyd, 2006; Federal Ministry of Finance, 2007). The latest evidence is that the Nigerian economy goes through a boom-and-burst as a result of variability in the price of oil (Akpokodje, 2000; Okonjo-Iweala, 2004). Nigeria's 2008 Appropriation Bill represents concrete evidence that the economy is essentially monocultural and depends heavily on oil revenue (Arowolo, 2007). The author concludes that the success or failure of the 2008 budget in Nigeria is intricately linked to the global oil market.

In a recent study, Warner (2005) indicates that oil producing African countries possess a potential to reap abundant resources in excess of requirements needed to meet their Millennium Development Goals. According to Wuthmann (2006), there are challenges facing oil producing African countries in terms of the management of cash flows associated with oil revenues. A study of public expenditure management in Anglophone African countries shows a disappointing performance due to poor revenue projections (Lienert and Sarraf, 2001). Moreover, the study report shows a poor control of expenditures and a lack of budget discipline. Babalola (2007) notes that Nigeria faced a long history of macroeconomic instability and fiscal imbalances due to fiscal deficits.

In a recent commentary, Nkwazema and Aderinokun (2007) quoted Nigeria's finance minister as saying that anticipatory expenditure failed because of the low benchmark approved for budgetary proposals. The minister further lamented that poor forecasting of total government revenue and overestimation of oil production are responsible for poor management of annual budgets in Nigeria. For example, the 2005 national budget was based on benchmark price of crude oil of $35 per barrel but the implementation of the budget was based on $40 per barrel. In order to address the problem of oil price forecasting, the Nigerian government sought the help of the International Monetary Fund experts who proposed a moving average [MA(q)] process for crude oil series (Federal ministry of Finance, 2007). Accordingly, the 2008 national budget was based on oil price benchmark of $53.83, a result reflecting the application of a 3.5-year moving average [MA(3.5)] or [ARMA(0, 3.5)] process.

By modeling a time series as a moving average process, one assumes that the time series is a stationary random process. More importantly, shocks to such a process have a Gaussian distribution. That is, shocks are independently and identically distributed with a zero mean and a positive but finite variance. Traditionally, most economic time series are modeled under the assumption of Gaussian distribution and linear random walks. However, with the work of Mandelbrot (1963), it is proven that several financial time series are non-linear and non-Gaussian. The non-linearity is attributable to accumulated long-term dependence in financial time series. In order to begin a program of effective planning for economic development in Nigeria, there is need to understand the data generating process for oil price series. Therefore, the objective of this paper is to test for a departure from linearity in Nigeria's Forcados oil price series. Specifically, this paper explores the presence of long memory in oil price series. If oil price series possess long memory, then a better modeling approach will be based on autoregressive fractionally integrated moving average [ARFIMA(p,d,q)] rather than an ARMA(p,q).

THE DYNAMICS OF OIL PRICE SERIES

A time series variable is generally classified stationary or nonstationary. Stationarity means that a time series will return to a constant mean in which case random shocks to the series are forgotten at a consistent rate (Lebo, 2001). Bennett (1979) observes that a stationary time series is one whose probability characteristics (such as mean and standard deviation) are invariant to time. A series is nonstationary if it wanders around without regularly returning to a particular value such as the mean. Thus, the best estimate of a distant value according to Harris (2002) depends critically on the current value of the series. In general, nonstationary variables do not have mean values because their long-run average values do not converge. A good example of a nonstationary process is a random walk model. Lebo (2001) notes that a stationary series contains only short-term memory.

Haubrich and Lo (2001), pose the question: are time series better approximated by fluctuations around a deterministic trend or by a random walk plus a stationary component? Mandelbrot (1971), was the first to suggest the possibility that asset price series could exhibit long range dependence or long memory. Mandelbrot (1972) raises the issue of long memory in stock price series. This is based on the premise that actual movements in time series are stochastically influenced by the recent to the most remote past. The study of long memory in time series data can be traced to Hurst (1951), however, a renewed application in the financial economics field has become more intense.

The decision to model a time series either as stationary or nonstationary has important consequences. A spurious result arises if a nonstationary series is modeled as a stationary series. Employing fractional integration methods can mitigate this problem. Crato and deLima (1994), observe that several economists agree that financial time series have a long memory because actual movements in the series are stochastically influenced by the recent to the most remote past. Long memory in a time series is indicative of persistence in the volatility of the series. Green (2000), notes that the autocorrelation for a stationary process decays at an exponential rate, thus, large values of autocorrelation typically cease to appear after a few lags. On the other hand, the autocorrelation of a nonstationary series remain persistently very high at long lags. Thus, Granger and Ding (1996), define a long memory series based on a slowly declining autocorrelation structure. According to Cheung and Lai (2001), long memory dynamics can confound unit root tests and undermine their ability to distinguish between low- and high-frequency dynamics. They note that long memory dynamics are properly taken into consideration when a researcher employs fractional times series methodology.

Moshiri and Faoutan (2006) conclude that movements in oil price series are complicated and that price series is subject to too much variability. One logical argument is offered in the climatology literature in which weather is said to be chaotic. Moshiri and Faoutan argue that since energy demand has a high correlation with weather conditions, then energy price series should be chaotic as well. Moreover, oil price hikes are dominated by shocks that are considered "exogenous" to the rest of the world (Jones and Kaul, 1996). These shocks manifest themselves in form of wars, OPEC actions, natural disasters and other disruptions to production. In view of the aforementioned, Pindyck's (2001) model seems logical when variability in oil price series is captured by the inclusion of oil inventory. In the model, the demand and supply functions are defined as:

$$D = D(P, z_1, \varepsilon_1) \quad (1)$$

$$S = S(P, z_2, \varepsilon_2) \quad (2)$$

Where D is demand function, S is supply function, P is the spot price, z_1 is a vector of demand-shifting variables, z_2 is a vector of supply-shifting variables, ε_1 and ε_2 are random shocks. If inventory level is represented by Q_t, then ΔQ_t which denotes a change in inventory level at time t is defined as:

$$\Delta Q_t = S(P_t, z_2, \varepsilon_2) - D(P_t, z_1, \varepsilon_1) \quad (3)$$

In Equation 3, ΔQ_t is defined as net demand (demand for production in excess of consumption). Therefore, equilibrium is established when net demand is set equal to net supply. Pindyck defines the price function as an inverse net demand function of the form:

$$P_t = f(\Delta Q_t; z_{1t}, z_{2t}, \varepsilon_t) \quad (4)$$

According to Equation 4, the market clearing condition in the cash market is stated as a relationship between the spot price and changes in the level of inventories. In this model, the effect of shocks to the system is captured by the level of inventories.

OIL AND ECONOMIC PLANNING IN NIGERIA

Crude petroleum can generally be classified as light, medium or heavy, depending on its gravity as measured by the American Petroleum Institute (API). The API gravity is a measure of the relative density of a petroleum liquid relative to the density of water. Nigeria's major oil products are Bonny Light and Forcados Light. They both have low levels of sulphur content which make them possess low corrosiveness to refinery infrastructure (www.wikipedia.com).

Ross (2003) reveals that Nigeria is the most oil-dependent country in the world in 2000. According to him, the volatility in the oil sector could lead to volatility in government revenues as the dependence on oil increases. This situation is significant, because the revenue generated by positive shocks, are usually squandered, thereby producing unhealthy rates of expansion in the size of the government. Moreover, Ross notes that positive shocks lead to a decline in the quality of public investments. These observations are consistent with those of Okonjo-Iweala (2004).

It is important for a country to experience a growth in investment. However, it is harmful for the quality of investment to fall. What Ross reports in his study of Nigeria is that the government relaxes its standards for selecting investment projects when it experiences an increase in oil revenue. This happens because of the desire to speed up economic growth or the pressure from rent-seeking politicians. Consequently, the desire to increase the quantity of investments had led to a decline in economic development. Therefore, it is imperative that government needs to institute a mechanism for planning and projecting oil windfalls. The starting point for such an effort is to identify the nature of the probability distribution of oil price series. Nigeria does not seem to do very well when compared with other oil producing countries in Africa. Its relatively low per capita GDP in 2003 is at $471 compared with Equatorial Guinea at $6,026. In terms of oil per capita, Nigeria lags behind many African producers in spite of a relatively large daily production of oil (Ayadi et al., 2009).

In the early years of oil discovery, Madujibeya (1976) catalogs its contributions to the Nigerian economy. These include employment opportunities, source of government revenues, supply of energy to industry, household and commerce, source of growth in GDP, and a source of foreign exchange reserves. The relative significance of manufacturing increased from 4.8 percent in 1960 to 8.2 percent in 1990. However, in 2000 and 2002, this sector of the economy had taken a big hit. As for the petroleum sector, its relative significance had dominated the other sectors especially since 2000. Therefore, while the petroleum sector grew in importance over time, the industrial sector did not experience much growth. The country became a member of the Organization of Petroleum Exporting Countries (OPEC) in 1971. In 2003, it was the fifth largest supplier of crude oil to the United States. It is the seventh largest producer of oil in the world. The economy of Nigeria is heavily dependent on oil because it accounts for over 90 percent of export revenues and over 90 percent of foreign exchange earnings. Over 80 percent of government revenue comes from this source. In 2003, Nigeria produced an average of 2.1 million barrels of oil per day. However, in 2004, OPEC raised Nigeria's production quota to 2.14 million barrels per day (Adedipe, 2004).

A general description of the performance of oil exporters relative to resource-poor nations of the world is captured by the phrase, "paradox of plenty" (Eifert et al. (2002). Many oil exporters including Nigeria are said to have performed worse than several resource-poor nations of the world. The capacity to engineer growth in these oil-rich nations has been hampered by the debilitating effect of volatility in export earnings (Akpokodje, 2000). There is no doubt that Nigeria has been negatively impacted by the fluctuations in its revenue from oil. In a previous attempt, Ayadi et al. (2000), model the interrelationship among a variety of macroeconomic variables representing the financial as well as the energy sectors of the Nigerian economy. The results reveal that the energy sector exerts a significant influence on the Nigerian economy by acting as a prime mover.

The Nigerian economy is dominated by the public sector and the bulk of the aggregate output is accounted for by exports and government expenditures (Anyamele, 2000). While analyzing the practice of foreign exchange budgeting in Nigeria, Anifowose (1995) notes that the size of the budget depends crucially on expectations of crude oil production and price. The reason is that about 90 percent of Nigeria's export earnings are from the sale of petroleum. Given that Nigeria is a member of OPEC, its production output of petroleum is exogenous because it is based on allocation to her by the OPEC cartel. Therefore, the reliability of Nigeria's revenue projection depends heavily on the ability of economic managers to project the price of oil. Anifowose (1995) reports that oil price projection is made by a linear extrapolation of the OPEC benchmark price.

Okonjo-Iweala (2004), a former minister of finance in Nigeria, posits that Nigeria goes through fiscal recklessness when oil price rises. She notes that past administrations in the country implement loose fiscal policy with its attendant flawed pattern of borrowing. The debt management strategies are classified as archaic and coupled with its fiscal policy, the economy goes through unnecessary boom-and-burst cycles. Moreover, Obadan (1993) notes that the Nigerian foreign exchange management is, seriously flawed. The author concludes that exchange rate management is predicated on methods that fail to achieve desired goals. Shortly after Nigeria achieved independence, Wolfgang Stolper served as the head Nigeria's Economic Planning Unit and observed that the process of planning was undertaken without much data (Stolper, 1966). Adedipe (2004) and Ayadi (2005) document the failure of the Nigerian government to balance it budgets for several years. All these represent anecdotal evidence that Nigeria's planning apparatus is defective.

It is ironic that the discovery of oil in Nigeria has not been associated with economic development (Akpokodje, 2000). Soremekun and Obi (1993) note that the emergence of oil as a mono-cultural base of the Nigerian economy has magnified the country's economic contradictions. The total impact of these contradictions is the "near permanent situation of national crisis," in which the nationalities of some parts of the country nurture feelings stymied by the other parts and thus are in search of reparation. Ross (2003) also notes that the discovery of oil in Nigeria had neither raised Nigerian income nor reduced poverty. According to Ross, between 1970 and 1999, oil generated about $231 billion in rents for the

Nigerian economy when valued in constant 1999 dollars. Relative to GDP, rents from oil accounts for between 21 percent and 48 percent of GDP since 1974. At the same time, per capita income in Nigeria has been declining at a rate of about 4 percent per year.

In the same sentiment, Forrest (1995) observes that the large windfall from oil had a number of unforeseen and unintended consequences. These include the power of government to bypass taxpayers in expending funds on unproductive "white elephant" projects. Moreover, there is a lack of public accountability in governance, neglect of non-oil tax revenue, an unnecessary expansion of state resources and a loss of control and discipline by those in positions of authority. Aiyegoro (1997) enumerates the outcomes associated with oil discovery in Nigeria to include over-bloated public sector, ambitious public projects, depreciating currency, badly implemented price and wage control, and the distortion of financial markets through bad public policy. Omotoye (1997) and Ojo and Ayadi (1984) support this viewpoint by also noting that the demise of agricultural sector is associated with oil discovery in Nigeria.

DATA AND METHODOLOGY

The data employed in this study is the weekly spot price series of Nigeria's forcados variety of crude oil from January 6, 1978 through August 3, 2007. There are 551 data points used. The data is obtained from the Energy Information Administration of the U.S. Daprtment of Energy.

In order to determine the presence of long memory in oil price series, the detrended fluctuation analysis (DFA) proposed by Peng et al (1994) is applied. Shieh (2006) argues that DFA permits the detection of embedded intrinsic self-similarity feature of a nonstationary time series. Moreover, it does not yield spurious detection of aparent self-similarity when compared with other methods such as fourier analysis. The DFA is employed to calculate the Hurst exponent through a logical set of operations. The first step involves the following estimation:

$$P(i) = \sum_{i=1}^{N} (P_t - p) \qquad (5)$$

Where N is the number of observations in the time series, P_t is oil price observation in time t, p is the arithmetic average price. In step number two, the accumulated time series is divided into boxes of same length of n. In each box (of length n), the trend is estimated by applying ordinary least squares (OLS) method. The OLS line in each box is identified as $P_n(i)$. To remove the trend in each box, $P_n(i)$ is subtracted from P(i). Then, the following quantity is calculated:

$$F(n) = \sqrt{\frac{1}{N}\sum_{i=1}^{N} [P(i) - P_n(i)]^2} \qquad (6)$$

The process described in the second step is repeated for every scale, n. The slope of the line relating log F(n) to log n determines the scaling (Hurst H) exponent which is also referred to as the self-similarity parameter.

Assume that the k^{th} order autocovariance is defined as:

$$\gamma(k) = Covariance[P_t, P_{t+k}] \qquad (7)$$

Then the k^{th} order autocorrelation can be determined as:

$$\rho_k = \frac{\gamma(k)}{\sqrt{Var(P_t)}\sqrt{Var(P_{t+k})}} = \frac{\gamma(k)}{\gamma(0)} \qquad (8)$$

Peters (1996) defines the autocorrelation function, ρ, as:

$$\rho = 2^{(2H-1)} - 1 \qquad (9)$$

If time series are random and uncorrelated, then the present has no effect on the future. The Hurst exponent, H, helps to infer the presence or otherwise of long memory in a time series. For example, if H = 0.5, then in Equation 9, the autocorrelation, ρ equals zero. The time series is then described as a Brownian motion which is also called a white noise process with independent increments that are identically normally distribted. It is also known as a random walk series. This type of process can be modeled using an ARMA(p,q) process. If $0 \leq H < 0.5$, then the underlying time series is said to be antipersistent or ergodic (Oh and Kim, 2006). The series is said to be "mean-reverting." The closer H is to zero, ρ moves closer to -0.5 indicating a negative autocoreelation. Peters (1996) note that such a time series is choppier and more volatile than a random walk series because of its frequent reversals. On the other hand, if $0.5 < H \leq 1.0$, then the time series is said to be persistent or trend-reinforcing. Persistent time series are also referred to as fractional Brownian series or biased random walks. Peters (1996) notes that in fractional Brownian series, correlation exists between events across time scales. Therefore, the probability of two events following each other is not fifty-fifty. The Hurst exponent is employed to describe such a probability. For example, with H=0.70, there is a higher probability that if the last change in a time series is positive, the next change will also be a positive. The higher probability is the source of the "bias" in the random walk process.

RESULTS

A cursory view of the descriptive statistics shows the time series is not normally distributed as depicted by the Jarque-Bera statistic. A kurtosis value of 2.59 is an indication of the presence of platykurtosis in the probability distribution of the series. This means the presence of tiny tails in the probability distribution of oil price series. In a tiny-tailed distribution, there is a lower-than-normal likelihood of a big positive or negative realization which represents non-symmetry. The autocorrelation and partial autocorrelation structures provide a summary of the dynamics of oil price series. The analysis shows a long lasting autocorrelation structure which suggests that the price process in nonlinear. The slow decay in the autocorrelation function is also indicative of the presence of long memory in oil price series.

Earlier in this paper we reported that the Nigerian federal budget was predicated on $53.63 benchmark price per barrel of crude oil and that the forecast was based on 3.5-year moving average process fitted to oil data. We revisited this model using weekly price series. A 3.5-year moving average is equivalent to a 182-week moving average. In terms of forecast error, the 182-week moving average process performed poorly as shown in Table 1. The measures of forecast error employed are mean absolute deviation (MAD), mean squared error (MSE) and mean absolute percent error (MAPE). As shown in Table 1, the 104-week moving average process performed better than the 182-week moving average process.

Table 1: Diagnostic Test Results for Moving Average Analysis of Oil Price Data

MA(q) in Weeks	Mean Absolute Deviation (MAD)	Mean Squared Error (MSE)	Mean Absolute Percent Error (MAPE)
MA(104)	**7.532**	**93.394**	**0.200**
MA(130)	**8.975**	**129.096**	**0.218**
MA(156)	**10.154**	**166.975**	**0.228**
MA(182)	**11.194**	**206.500**	**0.236**
MA(208)	**12.227**	**248.386**	**0.245**

Table 2 shows the results of the application of detrended fluctuation analysis (DFA) to weekly Forcados oil price series. The reported Hurst exponent is 0.48. This means, that the oil price series is anti-persistent or ergodic. Therefore, the Forcados oil price series is choppier and more volatile than a random walk series because of its frequent reversals.

Table 2: Detrended Fluctuation Analysis Results

H estimate : 0.4807058
Domain : Time
Statistic : RMSE
Length of series : 551
Block detrending model : x ~ 1 + t

Scale	4.0	8.0	16.0	32.0	64.0	128.0	256.0
RMSE	0.7998	1.1133	1.6119	2.2827	2.8852	3.7723	6.5738

CONCLUSION

Nigeria experienced a long history of macroeconomic instability since political independence. In an effort to arrest this problem, the federal government recently introduced structure into public budgeting. A Fiscal Responsibility Act was passed to improve the budgetary process. Consistent with the law, policymakers are required to devise a process for forecasting revenue. Thus, with the help of experts from the International Monetary Fund, an ARMA(p,q) process was recommended. As a mono-cultural economy with crude oil as the main source of government revenue, an ARMA(p,q) process assumes that oil price series is stationary with a short memory.

In this paper, we set out to test for the presence of long memory or persistence in oil price series using weekly data from 1978 through 2007. The results of the detrended fluctuation analysis (DFA) suggest Nigeria's oil price series is anti-persistent. A Hurst exponent of 0.48 is indicative of a time series that is covariance stationary but mean-reverting. In other words, we can fit a stationary ARMA(p,q) model driven by fractional noise to the series. This implies that a low price level has a tendency to be followed by a high price level and vice versa. Thus, past price trends are more likely to change in the future. Moreover, the effect of shocks to the price system dies away in the long run. Therefore, the current revenue forecasting tool would need to be overhauled in the presence of price reversals. This is more critical in the face of constant disruptions to oil production in the Niger Delta where the Forcados variety is produced.

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