DETECTING STRUCTURAL BREAK IN COMMODITY TIME SERIES DATA

by

NURUL NAJWA BINTI JATARONA

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Alhamdulillah, with His will has allowed me to complete this research.

First and foremost, I would like to thank Dr. Mohd Tahir Ismail, my supervisor, for his support throughout this project. His advices on both content and presentation has been superb, and quite simply, this project would not have been possible without his help. I am also indebted to Universiti Teknologi Mara (UiTM) for giving chance and helping my M.Sc study. My appreciation also goes to my parent for their unconditional loving support. A special note of gratitude goes to my sister and brother, Nurul Alifah Jatarona and Mohd Afiq Jatarona for their support, understanding and encouragement for all I needed during my graduate study. I would also like to thank my friends especially Masurah Mohamad, Khairulliza Ahmad Salleh, Siti Fatimah Ismail, Jufiza A Wahab and Sayed Kushairi Sayed Nordin who were always with me during this semester for their kind support and for everything they taught me. It is impossible to list the many friends and colleagues who over the year have assisted the development of ideas that have resulted in this research. To each of these people I express my sincere appreciation.

TABLE OF CONTENTS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

MENGENALPASTI PERUBAHAN STRUKTUR DALAM DATA SIRI MASA KOMODITI

ABSTRAK

Perubahan struktur adalah isu penting dalam data siri makroekonomi. Tujuan utama disertasi ini adalah untuk mengkaji perubahan struktur dan untuk menentukan tarikh berlakunya perubahan struktur di dalam harga komoditi ini menggunakan data bulanan. Kami menggunakan dua teknik yang berbeza; yang pertama menggunakan Ujian Punca Unit dengan Perubahan Struktur dan keduanya Ujian "Zivot dan Andrews" (1992) yang menentukan perubahan pada masa yang tidak diketahui. Keputusan kajian dapat menentukan perubahan struktur apabila menggunakan teknik yang berbeza tarikh perubahan juga berbeza untuk tempoh tahun 1989 hingga tahun 2009. Kami juga menjalankan Ujian "Bai Perron" (2003) yang mana membenarkan lebih dari satu perubahan struktur berlaku. Hasilnya kami dapat menentukan dua tarikh perubahan yang terbaik untuk ketiga-tiga komoditi.

ABSTRACT

Structural break is an important issue in macroeconomic time series data. The aim of this dissertation is to examine the structural break and to determine the exact break date in the price of commodity data using monthly data. We used two different techniques; first is Unit Root with Structural Break procedure and secondly is Zivot and Andrews (1992) test that allows for detecting a break at an unknown date. The results manage to detect structural break with different break date for different technique used during the period 1989 to 2009. We also conduct Bai Perron (2003) test allows for more than one structural break. The result show that we manage to detect the best two break date for all three commodities.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

It has been an ongoing debate on determining whether the shocks to macroeconomic time series are permanent or temporary. Nelson and Plosser (1982) discover that in any time series data, it must contain at least one unit root. This led to the findings that the random shocks have a permanent effect on the system. This was argued by Perron (1989) who suggested that a few unique economic events should be isolated and it must be considered that the pattern will change over time. Besides that many time series should not be modeled using an AR (*p*) process. Perron also comment on the results obtains by Nelson and Plosser (1982) that not really convincing for rare cases of occurrences or structural break that occur due to the infrequent permanent shocks. The approach also gives new evolution in identifying isolated economic events which given a way to test for breaks and break dates simultaneously. Therefore, Perron suggested the Augmented Dickey-Fuller (ADF) test which allowed for known or exogenous structural.

Since that, the break point can be determined from the data as suggested by many authors such as Zivot and Andrews (1992) and Perron (1997). Extended by the Zivot and Andrew (1992) model, Lumsdaine and Papell (1997) obtained a model that can accommodate two structural breaks in the data. However, it has been criticized by Lee and Strazicich (2003) for their treatment of breaks where there may be tendency for these tests to suggest evidence of stationarity with breaks. Then, Lee and Strazicich (2003) suggested a two break minimum Lagrange Multiplier (LM) unit root test where the alternative hypothesis unambiguously implies the series is trend stationary. All these finding gave a positive development of the literature on testing for unit roots.

This dissertation attempts to discover the structural break in price of commodity data. The question of whether a structural break occurred in the price of the precious metal which is gold, silver and platinum are of specific interest. Since precious metal is widely used in industrial, jewellery, medicine, automotive industry or in investment since 1970's until now, we shall examine the pattern, trend and the behavior of the prices. There must be any fluctuations in the price, large shock either increases or decreases through three decade period. All changes in the price of precious metal may occur due to the policy changes made by the government and banks, the demand and supply, change in consumer preferences, political condition and economic factors.

Therefore, a few methods will be used in detecting the structural break in the commodity data. Unit Root with Structural Break test is performed followed by Chow Test to verify the break date earlier. We also compare these results using a different test, which is Zivot and Andrews procedure to test the null of unit root against the break-stationary alternative hypothesis. Then, we also perform Bai Perron test in order to detect exist more than one break in commodity data.

1.2 Objective of Study

The objectives of this study are:

1. To determine whether there exist structural break in the commodity data.
2. To identify the exact time / date the structural break happen.
3. To analyze the reasons gold, silver and platinum having a structural change.
4. To compare which techniques are more robust.

1.3 Scope of Study

This study will be focused on determine the structural break. For the purpose of this study, we shall only concentrate on the time series data which is the commodity data for precious metal. We only use the price of gold, silver and platinum in finding the structural break.

1.4 Significant of Study

The findings from this study will contribute towards an enhanced understanding the pattern and behavior of the price of commodity data especially gold, silver and platinum. The key result in this model is that in future maybe will takes into accounts the structural breaks behavior when modelling the prices.

1.5 Outline Dissertation

The structure of the dissertation is organized as follows. It is divided into five main chapters. Chapter 1, briefly describe the development of the research related, introduce the main objective of the dissertation and the method use. In Chapter 2, describe summarise and evaluate the related past studies literature. The next chapter, which is Chapter 3, describes the methodological framework and outline of the structural break. Meanwhile, Chapter 4 describes the data, examine the results and lastly discuss on the results. Finally, Chapter 5 summarizes the main conclusion and points out some directions for future research.

where y_t is a time series of T observations and $\mu_t = \mu_0 + \mu_1 t$ are deterministic term (if $\mu_0 \neq 0$ there is a constant, and deterministic trend when $\mu_1 \neq 0$). The ADF statistic have a null hypothesis of a unit root process (i.e. $\rho = 0$) against the alternative of a stationary ($\rho < 0$ and $\mu_1 = 0$) or trend stationary ($\rho < 0$ and $\mu_1 \neq 0$) process. Nelson and Plosser (1982) mention that most macroeconomic time series, at least one have a unit root. The presence or absence of unit roots helps to identify the features of the data generating process of a series. If the unit root absence (stationary), the series of data will fluctuates around a constant long run mean and also shows that the series of data has a finite variance which does not depend on time. Furthermore, if the series is non-stationary it does not have a tendency to return to long run deterministic path and the variance of the series of data is time dependent. Basically, non-stationary series data will have a permanent effect from shocks and results the series will have a random walk. If the series of data is non-stationary and the first difference of the series is stationary, this means that the series of data contains a unit root. The main used of the unit root literature is to determine whether the time series are affected by transitory or permanent shocks.

Often, the issue in time series literature is the difficulty of differentiating between trend stationarity and difference stationary processes. Deterministic trends do not always appear to be linear and shocks sometimes have permanent effects. Another issue is the low power of ADF test and the inability to reject a false null of unit root, see for example De Jong *et al.* (1992). Therefore, the ADF-GLS test of Elliott, Rothenborg and Stock (1996) achieves improvements in power by estimating the deterministic regressors before estimating the autoregressive parameter. Knowing that when increasing the number of deterministic components (from no constant, to constant, to trend and constant) reduces the critical values and hence the ability to reject the null of unit root (or the power of ADF tests) Elliot *et al.* (1996) have developed tests based on GLS detrending. These tests are found to have both improved power and size properties compared than the conventional OLS-based ADF tests, see Elliot *et al.* (1996).

2.2 Exogenous Structural Breaks

The importance of structural breaks for the implementation and interpretation of unit root tests was first emphasized by Perron (1989) and Rappoport and Reichlin (1989). Perron (1989) mention structural change in time series can influence the results of tests for unit roots. Therefore, Perron's (1989) introduced a procedure that characterized by a single exogenous (known) break in accordance with underlying asymptotic distribution theory. Perron uses a modified Dickey-Fuller (DF) unit root tests that includes dummy variables to account for one known or exogenous structural break. The break point of the trend function is fixed (exogenous) and chosen independently of the data. In particularly, time series for which an uncritical application of ADF-type tests infers the existence of a unit root may often better be characterized by a single permanent break in a deterministic component of a stationary or trend-stationary process. Perron results are based on the following general ADF model with shifts in mean and trend

$$\Delta y_t = \rho y_{t-1} + \sum_{j=1}^{p-1} \gamma y_{t-j} + \mu_t \qquad (2)$$

where $\mu_t = \mu_0 + \mu_0^s d_{tTB} + \mu_1 t + \mu_1^s (t-T_B) d_{tTB}$ are the possible deterministic terms (which contains a constant when $\mu_0 \neq 0$ and deterministic trend when $\mu_1 \neq 0$). The break date is at time T_B.

Perron (1989) identified three trend break models based on equation (2): **a crash** model which contains a linear trend with an intercept shift which is as follows;

$$\mu_t = \mu_0 + \mu_0^s d_{tTB} + \mu_1 t \tag{3}$$

$$d_{tTB} = \begin{cases} 0, & t < T_B \\ 1, & t \geq T_B \end{cases}$$

a **changing growth** linear trend model with a change in slope of the linear trend and the two segments joined at the break date (this may characterize a productivity slowdown);

$$\mu_t = \mu_0 + \mu_1 t + \mu_1^s (t-T_B)\, d_{tTB} \tag{4}$$

$$d_{tTB} = \begin{cases} 0, & t < T_B \\ 1, & t \geq T_B \end{cases}$$

and finally a **combined model** with intercept and slope change.

$$\mu_t = \mu_0 + \mu_0^s d_{tTB} + \mu_1 t + \mu_1^s (t-T_B)\, d_{tTB} \tag{5}$$

$$d_{tTB} = \begin{cases} 0, & t < T_B \\ 1, & t \geq T_B \end{cases}$$

Each of the three models has a unit root with breaks under the null hypothesis since the dummy variables are incorporated in the estimated regression under the null hypothesis and for the alternative hypothesis is a broken trend stationary process.

Perron (1989) also conducted a Monte Carlo study and found that with a significant shift and using significant ADF tests it could rarely reject the unit root hypothesis even though we have a stationary process with a broken trend. While Elliot *et al.* (1996) with a GLS correction was able to improve upon the power of OLS-based ADF tests, this is also susceptible to breaks in the original series.

2.3 Endogenous Structural Breaks

Perron (1989) approach and results were important. However, the Perron (1989) method of assuming the break date as exogenously determined and known *ex ante* has often been considered as inappropriate in the subsequent and empirical literature. Since then, there are several studies have developed using different methodologies for endogenously determining the break date. According to Christiano (1992), Banerjee, Lumsdaine and Stock (1992), Zivot and Andrews (1992), Perron and Vogelsang (1992) and Chu and White (1992), identification of the break date may not be unrelated to the data and if the critical values of the test assume the opposite, there may be substantial size distortions (i.e. the tests will have a tendency to over reject the null hypothesis of unit root).

Based on Zivot and Andrews (1992), the endogenous structural break test is a sequential test which utilizes the full sample and uses a different dummy variable for each possible break date. Then, the break date is selected where the t-statistic from the ADF test of unit root is at minimum (i.e. most negative). Consequently a break date will be chosen the evidence is least favorable for the unit root null. The minimum t-statistic value of Zivot and Andrew (1992) has its own asymptotic theory and critical values which are different to the critical values in Perron (1989). The differences are the selecting of the time of the break is treated as the outcome of an estimation procedure rather than predetermined exogenously.

Banerjee *et al.* (1992) also tests for endogenous break dates and utilises sequential, rolling and recursive tests. Then, the non-sequential tests use sub-samples to determine the number of breaks and can be viewed as not being using the full information set, which the implications may occur for the power of these tests. The tests include the maximum DF statistic, the minimum DF statistic and the difference between the two statistics.

Then, Zivot and Andrews (1992) and Banerjee *et al.* (1992) test the joint null hypothesis of a unit root with no break in the time series. As the consequences, accepting the null hypothesis in the context of the Zivot and Andrews (ZA) and Banerjee *et al.* (2005) tests does not imply unit root but rather unit root without break. But Perron (1994) considers a test of the unit root hypothesis where the change in the slope is allowed under both the null and alternative hypotheses. Critical values that derived for ZA and B tests assumed that there are no structural breaks under the null. But Nunes *et al.* (1997) suggest that there may be some size distortions where such critical values are used in the presence of structural breaks under the null hypothesis.[1]

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[1] Garcia and Perron (1995) consider breaks in real interest rates and estimate structural break dates using a Markov Switching model.

2.4 Gold, Silver and Platinum as a Precious Metals

Among all the commodities that are traded and consumed, gold, silver and platinum is considered as a precious metal. This due to their relative scarcity and high economic value, the composition of their demands differs widely. Furthermore, investment which include jewelry, accounts for about 90% of the demand for gold, while industrial use occupies approximately two thirds of the total demand for platinum (O'Connell, 2005). Ciner (2001) investigate that the disappearance of the stable long-run relationship between gold and silver on the Tokyo Commodity Exchange in the 1990s. Ciner (2001) also states that more recently gold and silver have had their own separate markets as they ate considered to have different economic uses. However, Lucey and Tully (2006) suggest that an overall stable relationship persists even if there are periods when the two precious metals are weakly related. Sari *et al.* (2007) argue that a strong relationship between gold and silver, while highly cyclical copper appears to be nearly independent of movements in the prices of oil, gold and silver. This proves that they find evidence that the gold and silver can explain some of the forecast error variance of changes in oil futures prices.

CHAPTER 3

DATA AND METHODOLOGY

3.1 Data

The data used in this study consist of monthly average prices of gold, silver and platinum. The data cover the period from January 1989 until December 2009, for total 252 observations. The data was provided by the website www.kitco.com. The price of gold, silver and platinum, expressed in US dollar per ounce. In order to analyze the data, we will use both software JMulti and RATS 5.0.

Table 1 Variables and sample period

Series	Sample period
Gold	1989 M1-2009 M12
Silver	1989 M1-2009 M12
Platinum	1989 M1-2009 M12

Source: All data are extracted from www.kitco.com. All variables are taken in log

3.2 Methodology

3.2.1 Unit Root With Structural Break

For the purpose of time series analysis the price of commodity data, we begin through testing the presence of a unit root with structural break using JMulti. The unit root with structural break test which investigate by Saikkonen and Lütkepohl (2001) has a form

$$y_t = \mu_o + \mu_1 t + f_t(\theta)'\gamma + x_t \tag{6}$$

is considered, where θ and γ are unknown parameters and the errors x_t are generated by an AR(p) process with possible unit root. An AR (p) process can be represent of order p,

$$b(L)(1-\rho L)x_t \tag{7}$$

where

$$b\,(L) = 1 - b_1 L - \ldots - b_{p-1} L^{p-1} \tag{8}$$

which if $p > 1$, it has all zeros outside the unit circle whereas $-1 < \rho \leq 1$. If $p = 1$, therefore we can say that unit root present.

There are three possible shift functions.

The first shift function is a simple shift dummy variable with shift date T_B.

$$f_t^{(2)}(\theta)=\begin{cases}0, & t<T_B\\ 1, & t\geq T_B\end{cases} \tag{9}$$

where the parameter γ is a scalar. When we differencing this shift function, it will leads to an impulse dummy.

The second shift function is based on the exponential distribution function which allows for a nonlinear gradual shift to a new level starting at time T_B,

$$f_t^{(2)}(\theta)=\begin{cases}0, & t<T_B\\ 1-\exp\{-\theta(t-T_B+1)\} & t\geq T_B\end{cases} \tag{10}$$

where both θ and γ are scalar parameters.

The third function can be viewed as a rational function in the lag operator applied to a shift dummy d_{1t},

$$f_t^{(3)}(\theta)=\left[\frac{d_{1,t}}{1-\theta L}:\frac{d_{1,t-1}}{1-\theta L}\right]' \tag{11}$$

The actual shift term is $\left[\gamma_1(1-\theta L)^{-1}+\gamma_2(1-\theta L)^{-1}L\right]d_{1t}$, where θ is a scalar parameter between 0 and 1 and $\gamma=(\gamma_1:\gamma_2)'$ is a two-dimensional parameter vector. Based on the Saikkonen and Lütkepohl (2001) and Lütkepohl et al. (2001) it assumed that the shift point τ is known a priori. In the other words, the break point τ will be regarded as an unknown integer valued parameter. According to Lanne et al. (2001) recommend choosing a reasonably large AR order in a first step and then picking the break date which minimizes the GLS objective function used to estimate the parameters of the deterministic part if the break date is unknown. Besides that, based on Lanne et al (2001), the order of AR is not important as long as the order is chosen appropriately. Therefore, we used shift dummy as a shift function with lag two to find the break date for each commodity data.

3.2.2 Chow Test

In order to test whether the break date given is significant or not, we need to test the break date. We will test the break date using a VAR analysis under stability analysis, which is Chow Test. Chow Test, was developed by Gregory C. Chow (1960) but here we are using the extension developed by B. Candelon, H. Lütkepohl (2001). Here the basic VAR (p) model considered has a form

$$y_t = v + A_1 y_{t-1} + \ldots + A_p y_{t-p} + u_t \quad (t = 1, \ldots\ldots, T) \tag{12}$$

where v is a constant vector, the A_i are coefficient matrices and $u_t = (u_{1t}, \ldots, u_{nt})'$ is an unobservable zero mean white noise process with time invariant positive definite covariance matrix $\sum$, i.e. $u_t \sim iid(0, \sum)$. Here we will consider two versions of Chow tests contain a sample split (SS) test and break-point (BP) tests. Basically, we will assume that a structural break may have occurred in period T_B.

The sample split (SS) test statistics can be written as follows:

$$\lambda_{SS} = (T_1 + T_2)\log\det\hat{\Sigma}_{1,2} - T_1\log\det\hat{\Sigma}_{(1)} - T_2\log\det\hat{\Sigma}_{(2)} \approx \chi^2(k) \qquad (13)$$

where k is the number of restrictions imposed by assuming a constant coefficient model for the full sample period, which is k is the difference between the sum of the number of coefficients estimated in the first and last sub periods and the number of coefficients in the full sample model. We does not take into consideration that the potentially different parameters in the white noise covariance matrix where it is not counted. If the value of the test statistics λ_{ss} is large, the parameter constancy hypothesis will be rejected.

The break-point (BP) test statistics has the form:

$$\lambda_{BP} = \frac{1-\left(1-R_r^2\right)^{1/s}}{\left(1-R_r^2\right)^{1/s}} . \frac{Ns-q}{nk} \approx F(nk, Ns-q) \qquad (14)$$

where

$$s = \left(\frac{n^2k^2-4}{n^2+k^2-5}\right)^{1/2}, \quad q = \frac{nk}{2}+1, \quad N = T-k_1-k-(n-k+1)/2$$

With k_1 being the number of regressors in the restricted, stable model and

$$R_r^2 = 1-\left(\frac{T_1}{T}\right)^n |\hat{\Sigma}_{(1)}\left(|\hat{\Sigma}|\right)^{-1}$$

We take into consideration that the potentially different parameters in the white noise covariance matrix where it is counted. Here, the null hypothesis will be rejected if the λ_{BP} has large values.

3.2.3 Zivot and Andrews Test

Since the entire commodity data had only detected one break date at a time, we want to test the break date which only permits a one-time structural break. Therefore, we perform the Zivot and Andrews test which only allows one-time structural break. Zivot and Andrews suggest a variation of Perron's original test which they assume that the exact breakpoint/date is unknown. Based on Perrön, data algorithm is used to proxy Perron's procedure which is to determine the breakpoints. Based on the Perron's characterization of forming the structural break, Zivot and Andrews considered three models of structural break under the null and alternative hypotheses to test for a unit root.

The models equations are as follows:

$$\Delta y_t = c + \alpha y_{t-1} + \beta t + \gamma DU_t + \sum_{j=1}^{k} d_j \Delta y_{t-j} + \varepsilon_t \qquad \text{(Model A)}$$

$$\Delta y_t = c + \alpha y_{t-1} + \beta t + \theta DT_t + \sum_{j=1}^{k} d_j \Delta y_{t-j} + \varepsilon_t \qquad \text{(Model B)}$$

and

$$\Delta y_t = c + \alpha y_{t-1} + \beta t + \theta DU_t + \gamma DT_t + \sum_{j=1}^{k} d_j \Delta y_{t-j} + \varepsilon_t \qquad \text{(Model C)}$$

The null hypothesis in the three models is $\alpha = 0$, where all the series contains a unit root with a drift that excludes any structural break, while the alternative hypothesis $\alpha < 0$ where all the series having a trend stationary process with a one time break which occurring at an unknown point in time. Model A permits an exogenous change in the level of series, Model B allows an exogenous change in the slope of the trend function and Model C admits both change in the level and the slope of the trend function.

Using the Zivot and Andrews test, it took each point as a potential break date (TB) and runs a regression for every possible break date sequentially. Based on Perron, commonly most economic time series data can be adequately modeled by either using Model A and/or Model C. Based on Sen (2003) shows that if one uses Model A when in fact the break occurs according to Model C then there will be a substantial loss in power. But, if the break occurs in Model A when the Model C is used then the loss of power is minor. Therefore, in this test we choose Model C for our analysis of unit root.

3.2.4 Bai Perron Test

Since Unit Root with Structural Break and Zivot and Andrew test display only one break date, now we will consider the test which will detect more than one break at one time. Lumsdaine and Papell (1997) suggested that considering only one endogenous break may not be sufficient and it could lead to a loss of information when actually there are more than on break. Bai and Perron (1998) discuss simultaneous estimation of multiple break dates. Therefore, we will use the Bai Perron test in order to check whether there exists more than one break in the commodity data.

The model suggested by the Bai and Perron (1998) are as follows:

$$y_t = x_t'\beta + w_t'\delta_j + \varepsilon_t \qquad t = T_{j-1}+1,\ldots\ldots,T_j \qquad (15)$$

Based on this model, y_t is the dependent variable at time t, x_t and w_t are vectors of covariates and β and δ_j are the corresponding vectors of coefficients where j = 1, ……., m+1 and ε_t is the disturbance at time t. The break points (T_1,……T_m), are treated as unknown. In this test, we will estimate the unknown regression coefficients and the break points when T observations on (y_t, x_t, w_t) are available. This model is a partially structural change model and since the parameter β is not shifted therefore it is estimated using the entire sample. When the $p = 0$, we will obtain a pure structural change model where all the coefficients are subject to change. Then, it is known that the variance of ε_t is not necessary to be constant. The Bai and Perron test conducted using RATS software and the result is display in Chapter 4.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Unit Root with Structural Break

It is known that the Unit Root with Structural Break test only detects one break at a time for each of the commodity data. We used shift function as a shift dummy and number of lag chosen is two. Based on Table 2, commodity gold and silver, the break date detected is on June 2006, while for commodity platinum, the break date detected is on February 2008.

Table 2 Break Date for commodity data

Series	Break date
Gold	2006 M6
Silver	2006 M6
Platinum	2008 M02

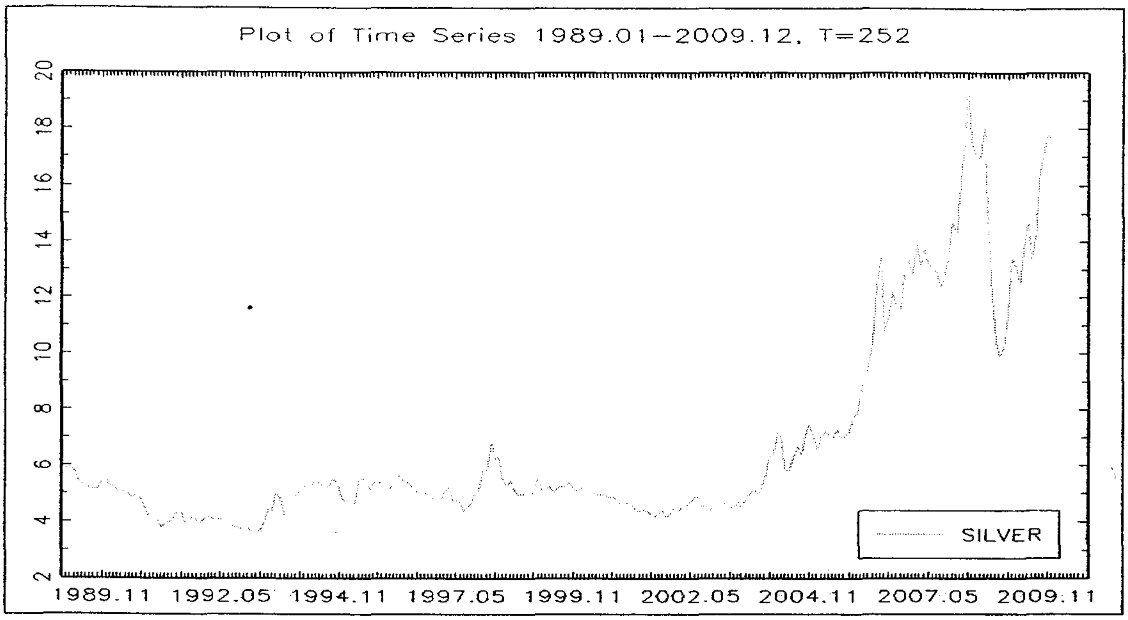

Figure 2 Time Series plot of Silver

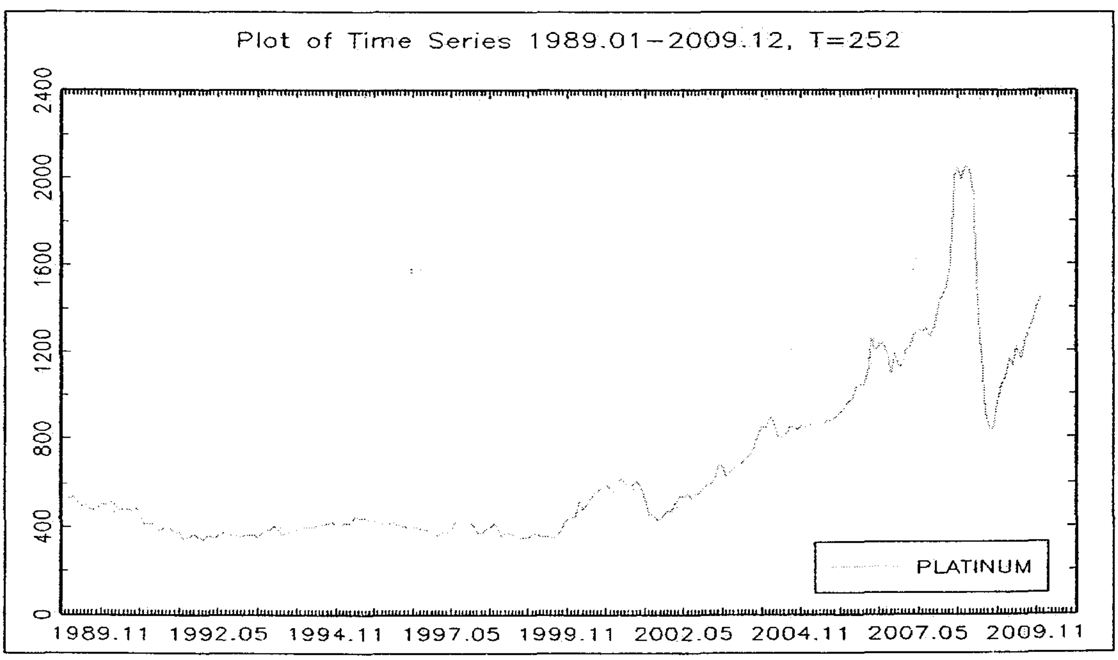

Figure 3 Time series plot of Platinum

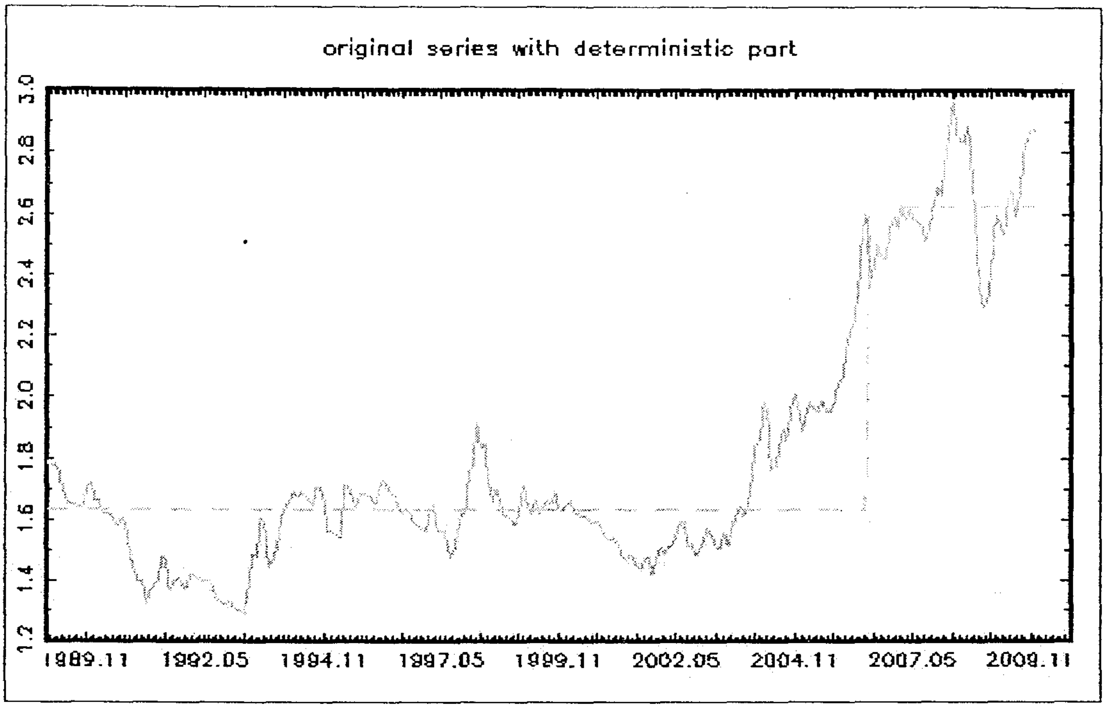

Figure 6 Time Series Plot of Silver using Unit Root with Structural Break Test

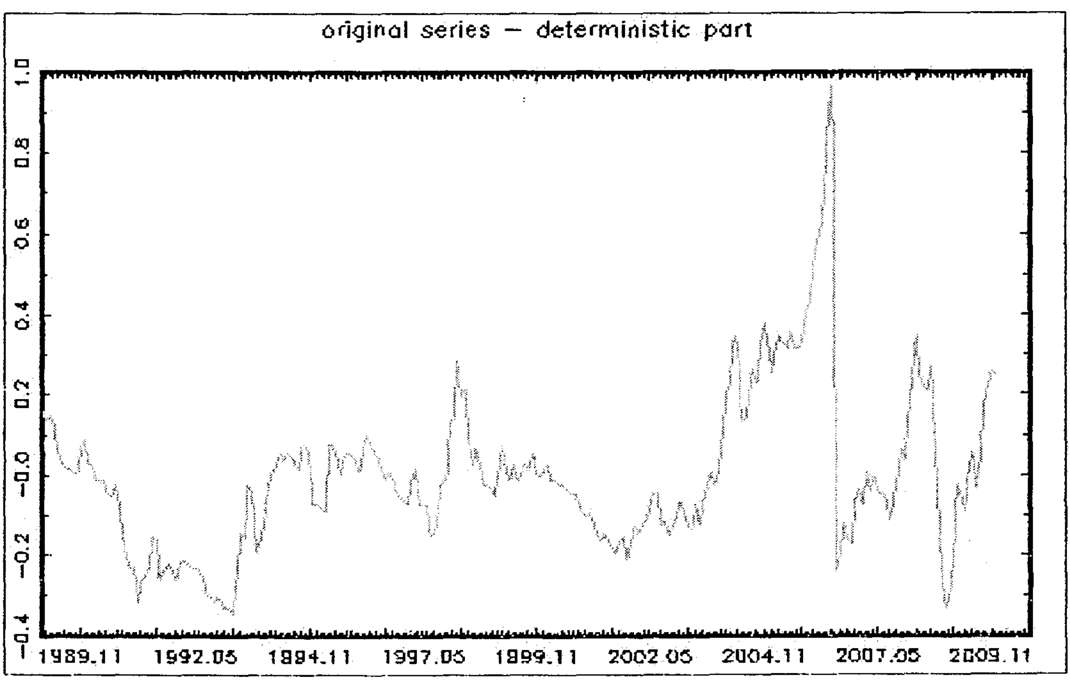

Figure 7 Deterministic part of Silver

It is known that like all other commodities and liabilities, the price of gold also driven by supply and demand. Therefore, many demographers forecast that the price of these commodity will set to rise based on the increased of the world population, and the emergence newly industrialized economies which led by the Asian country especially China,' India and the Middle East.

In China, gold is considered as a symbol of prosperity and good fortune. Usually they believe that the wealth should be preserve from one family till the entire generations. While for India, gold is the most common gift. In wedding ceremony, gold is used as a bride's dowry and also used as jewelry. The common wedding season is between December to May and on average it is about eight million marriages each year. Therefore, sometimes it is noticeable when there are spikes in global gold demand during those months. Different case for the Middle East country, the increase in demand of gold is based on the wealth of the oil.[3]

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[3] Why the price of gold is set to rise http://www.moneyweek.com/investments/precious-metals-and-gems/why-the-price-of-gold-is-set-to-rise.aspx