# UNIVERSITY OF CRETE

## FACULTY OF SOCIAL SCIENCES

### DEPARTMENT OF ECONOMIC SCIENCES


**Postgraduate Thesis**
**for**
**Postgraduate Program “Economic Theory and Policy”**

**Title: Econometric Analysis of the effects of structural breaks in stock market indices, evidence from France, Germany, England , USA and Greece**


**George Papadakis**

**Supervisor:**

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| Professor University of Crete | Professor University of Crete | Lecturer University of Crete |



**Rethimno, February 2011**

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Was approved by the three-member examining committee …………………………

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## Abstract

The theme of unit roots have received a great amount of attention in terms of theoretical and applied research over the last three decades. Since the seminal work by Nelson and Plosser (1982), testing for the presence of a unit root in the time series data has become a topic of great concern. This thesis employs monthly data covering the period 1993-2009 and examines the short and long-run relationships between the German Aktien index (DAI), the Athens Stock exchange Index (ASEI), the French CAC40, the FTSE100 and the Dow-Jones industrial Average index (DOW). The research methodology adopted examines the presence of structural brakes in the time series of the aforementioned Stock Exchange price indices. The results clearly show that when we allow for a structural break under both the null and alternative, the null hypothesis of Unit root for all the five series can not be rejected, therefore we *conclude the existence of a unit root* and a structural break in the form of either Model (A) or Model (C). We test using both Model A and Model C using the GAUSS codes for the one structural break Minimum LM test of Lee and Strazicich and then two-break Lagrange Multiplier (LM) unit root test.



**SUBJECT AREA:** Econometric Methodology and Analysis

**KEYWORDS:** Unit Roots, Structural Breaks, Stock Market Indices

# Contents

## Introduction

The purpose of an international investor is to minimize his/her portfolio risk at a given level of expected return. The modern portfolio theory suggests that low correlations between assets result in lower risk where return on the portfolio is measured by its mean and risk is measured by its standard deviation. From the perspective of an international investor who is willing to make portfolio investments in the world's advanced financial markets it is important to know if he can achieve diversification. Accordingly, correlation has been used as the main indicator of diversification within asset classes and on international basis within countries. Developed countries with higher economic and trade linkages amongst them, had higher correlation and as a result assets traded in their capital markets responded to certain common factors. This thesis is not going to present any test for correlation and for this reason we cannot draw a conclusion potential interdependencies among the stock market indices which are referred above.

The first part of the study is composed by chapter 1 ,2, 3, 4, 5 introduce an extensive literature review in the field of unit roots and structural breaks formulates hypotheses which are to be tested in the empirical part and presents the tests to be applied. The second part is consisted of chapter 6 presents the available data and defines the methodology adopted. The next part of the paper chapter 7 exhibits the results and discusses the empirical findings based on the events from the relevant stock markets the years under investigation. Finally conclusions are drawn and future research directions are suggested.

## Literature Review

Before we start analysing in detail the unit root testing in the presence of structural breaks we make a reference in the literature review about interdependency among major world financial markets because this part constitute the continuity of this thesis.

In the context of globalization, through a growing process of economic integration among countries and financial markets, the interdependency among major world financial markets becomes more and more evident. The interdependency between financial markets has been at the focus of interest since the 1960´s decade. A handful of studies in that early period provide evidence that the degree of interdependency between international markets is quite low. This limited interdependency is attributed to the legal and technical restrictions on the movements of capital among countries.

Later on, when these restrictions were abolished, the degree of interdependency between markets increased. In the meanwhile, portfolio managers willing to reduce the systematic risk related to a specific market, and benefit through the diversification, started investing in more than one country. This resulted in a further increase in the independency among countries. During the decades of 1980 and 1990, this attracted the interest of the academic community in an effort to analyze the structure of the interdependencies and reach conclusions on the driving forces and implication for asset pricing. Consequently, a number of different econometric techniques were employed to investigate the said interdependency, especially the short-term effects, among markets. The development of the cointegration theory from Engle and Granger {1987}provided the theoretical framework for the building up of models in the context of which both short and long term relations among international markets can be examined.

The majority of the studies that followed confirmed that there is a considerable degree of interdependency among markets, predicting a considerable increase through time. That is mainly due to the globalization process, the abolishment of any restrictions in capital movements as well as the improvement of telecommunications [Internet]. Table 1, summarizes the main studies analyzing market interdependency.

**Table 0:** Published Work on the Interdependency of World Stock Markets

| Study | Markets | Period | Methodology | Results |
|---|---|---|---|---|
| 1.Eun and Shim (1989) | Australia, Canada,France, Germany, Hong-Kong, Japan, Switzerland, Britain, USA | 1980-1985 | VAR model Impulse responses | Market Interdependency USA exerts dominant influence |
| 2.Taylor and Tanks (1989) | Britain,Germany, USA,Holland, Japan | 1973-1979 1979-1986 | Cointegration and Granger test | Market cointegration between Britain, Germany, Japan and Holland after the abolishment of currency restrictions in Britain 1979 |
| 3.Koch and Koch (1991) | Japan, Australia, Singapore, Hong- Kong, Switzerland Germany,Britain, USA | 1972,1980,1987 | Dynamic System of Simultaneous Equations | Interdependency between markets within a 24 hour period. Also the geographic proximity influences positively the interdependency |
| 4.Yan-Leung Cheung and Sui-Choi Mak (1992) | USA, Japan, Hong-Kong, Malaysia, Indonesia, Philippines, S.Korea, Taiwan, Tailand | 1978-1988 | Cointegration test | The USA markets exert dominant influence in most of the cases under examination. |
| 5.Malliaris and Urrutia (1992) | USA,Japan, Britain, Hong-Kong, Singapore, Australia | Μάιος 1987 - Μάρτιος 1988 | Granger causality test | No Granger causality among markets before and after the crash of October 1987. The dominant role of USA is not confirmed. |
| 6.Kasa (1992) | USA, Britain, Germany, Japan, Canada | 1974-1990 | Error correction model | The stochastic trend behind the long-run movement of markets is more important in Japan and less important in Canada. |
| 7.Arshanapalli and Doukas (1995) | Britain,Germany, USA,France, Japan | 1980-1990 | Cointegration test | Before 1987 crush there was no dependency among the European stock exchanges and that of the New York. After the crush there was. The dominant role of USA is also confirmed. The Japanese market does not relate with other markets. |
| 8.Bayers and Peel (1993) | USA, Britain, Germany, Japan and Holland | 1979-1989 | Cointegration test | There is no interdependency among the 5 markets and as a result there is no long run relationship among them. |
| 9.Blackman, Holden and Thomas (1994) | 17 Stock Markets | 1970-1979 και 1984-1989 | Cointegration test | There is cointegration during the second period under examination. |
| 10.Richards (1995) | Australia, Austria, Canada,France, Germany,Denmark, Hong-Kong, Italy, USA,Japan,Britain,Sweden, Switzerland, Holland, Norway, Spain | 1970-1994 | Cointegration test | There is no interdependency among the markets under investigation |
| 11.Hassan and Naka (1996) | USA,Britain, Germany,Japan | 1984-1991 | Vector error correction model (VECM) | There is an increasing interdependency among markets in the short as well as in the long run. The dominant role of the USA is established |
| 12.Koutmos (1996) | Britain,France, Germany,Italy | 1986-1991 | Multivariate VAR-EGARCH model | There is interdependency among European markets There is an asymmetry in the transmission mechanism of the error variance |
| 13.Both, Martikainen and | Denmark, Norway, Sweden, Finland | 1988-1994 | Multivariate VAR- | Independency of markets despite the trade relations among them |

| | | | | |
|---|---|---|---|---|
| Ken (1997) | | | EGARCH model | There is an asymmetry in the transmission mechanism of the error variance |
| 14.Choudhry (1997) | Arzentina, Brazil, Chile, Colombia, Mεxico, Venezuela, USA | 1989-1993 | Cointegration test | The markets are cointegrated with or without the presence of the USA which appears to exert dominant influence. |
| 15.Elyasiasi, Perera and Puri (1998) | Sri Lanka, Taiwan, Singapore, Japan, S.Korea, Hong-Kong, India, USA | 1989-1994 | Multivariate VAR model | The market of Sri Lanka is not influenced by any other market. |
| 16.Moschos and Xanthakis (1998) | Britain,USA, Greece | 1990-1992 | Autoregressive model | The changes of S&P 500 of New York contribute to improved predictions in the movement of the Athens Stock Exchange The changes in the Athens Stock Index are attributed mainly on domestic factors. |
| 17.Janakiramanan and Lamba (1998) | Australia, Hong-Kong, Japan, New Zeland, Singapore, USA, Indonesia, Malaysia, Tailand | 1988-1996 | VAR models | Countries which are geographically close with strong economic ties appear to be financially interdependent and highly integrated. The dominant role of the USA market is confirmed. |
| 18.Huang, Yang and Hu (2000) | USA, Japan, China, South Growth Triangle (Hong-Kong, Taiwan, South China) | 1992-1997 | Cointegration test, Granger causality test | There is no cointegration among the countries of the SCGT and also no long –r un relationship is found among the countries of the SCGT and Japan or the USA. In the short-run the USA market leads the rest. |
| 19.Chen, Firth and Rui (2000) | Brazil, Mexico, Chile, Arzentina, Kolombia, Venezuela | 1995-2000 | Cointegration test | There is cointegration among the markets under examination up to 1999. Since then though this long-run relationship breaks down. |
| t 20 .Östermark (2001) | Finland and Japan | 1990-1993 | Cointegration test | Cointegrated markets. |
| 21.Masih and Masih (2001) | USA, Britain, Japan, Germany, S.Korea, Singapore, Hong-Kong, Taiwan, Australia | 1992-1994 | Cointegration test | There is interdependency among the Asian markets and the already developed countries of the OECD. The markets of the USA and Britain have a dominant role both in the short and the long-run. |
| 22.In, Kim, Yoon and Viney (2001) | Hong-Kong, Korea, Tailand | 1997-1998 | Multivariate VAR-EGARCH model | Cointegrated markets. Hong-Kong plays a dominant role |

*The above table is from the paper Michalis Glezakos, Anna Merika, Haralambos Kaligosfiris., 2007. ‘Interdependence of Major World Stock Exchanges: How is the Athens Stock Exchange Affected?’. EuroJournals Publishing, Inc. 2007, pp. 1-16

# Chapter 1

## 1.1 Unit Root testing in the Presence of Structural Breaks: Econometric Methods and Motivation

The unit root hypothesis has attracted a considerable amount of work in the economics and econometrics literature. One of the most important empirical applications in this field was the work of Nelson and Plosser (1982) who found that most macroeconomic variables can be considered as univariate time series featuring a unit root. This empirical finding triggered an abundance of research of both empirical and theoretical scope.

The availability of the Dickey-Fuller statistical methodology (1979) for testing for the presence of a unit root in a time series under various modeling assumptions incorporating drift or deterministic time trend (or both) in the model lead to several empirical analyses basically confirming the findings of Nelson and Plosser (e.g. Stulz and Wasserfallen (1985) and Wasserfallen (1986)), applying this statistical methodology to other economic time series. These studies affected economic theorizing providing confirmation that many economic series like consumption (Hall (1978)), velocity of money (Gould and Nelson (1974)) and stock prices (Samuelson (1974)) follow the unit root specification. Alternative approaches to testing for a unit root also emerged, with the most prominent being the ones proposed by Phillips and Perron (1988), Campbell and Mankiw (1987,1988) and Cochrane (1988). Statistical tools were developed leading to the famous cointegration framework of Engle and Granger (1987) analyzing the relationships between time series variables exhibiting unit roots and multivariate systems (e.g. Stock and Watson (1988)).

This unit root revolution has a number of implications for macroeconomic theories, the most important being that under a unit root hypothesis, random shocks have a permanent effect on the system, that is the fluctuations are not transitory. This goes directly against the prevailing view that business cycles are transitory fluctuations around a stable trend path. The fact that a unit root allows shocks to have a permanent effect on a series and the important theoretical implications for the behavior of economic time series calls for a careful and reliable framework for testing the unit root hypothesis.

The certainty that most economic time series are characterized by a unit root, founded on the results of the aforementioned literature was seriously challenged by Perron (1989). In a seminal work, he argues that in the presence of a structural break, the standard ADF tests are biased towards the non rejection of the null hypothesis. Perron argues that most macroeconomic series are not characterized by a unit root but rather that persistence arises only from large and infrequent shocks, and that the economy returns to deterministic trend after small and frequent shocks. According to Perron, 'Most macroeconomic time series are not characterized by the presence of a unit root. Fluctuations are indeed stationary around a deterministic trend function. The only 'shocks' which have had persistent effects are the 1929 crash and the 1973 oil price shock' (1989, pp.1361). It is instructive in order to understand the problem of unit root testing under structural breaks to follow Perron's motivation, and we will do so in the next few pages.

# Chapter 2

## 2.1 Perron's framework for Unit root testing under Structural breaks, when the break date is exogenously given

Perron's null hypothesis is that a given series $\{y_t\}_0^T$ of which a sample of T+1 observations is available, is a realization of a time series process characterized by the presence of a unit root and possibly a nonzero drift. However, he allows for a one-time change in the structure at some time $T_B$ (1 < $T_B$ < T). Under the null three different models are considered: one that permits an exogenous change in the level of the series (a "crash" model), one that permits an exogenous change in the rate of growth, and one that allows both changes. The hypotheses are parameterized as follows:

***Null Hypotheses:***

Model(A) $y_t = \mu + dD(TB_t) + y_{t-1} + e,$

Model(B) $y_t = \mu_1 + y_{t-1} + (\mu_2 - \mu_1)DU_t + e_t,$

Model(C) $y_t = \mu_1 + y_{t-1} + dD(TB)_t + (\mu_2 - \mu_1)DU_t + e_t,$

Where

$D(TB)_t = 1$ if $t = T_B + 1$ and 0 otherwise;

$DU_t = 1$ if $t > T_B$ and 0 otherwise;

$A(L)e_t = B(L)\upsilon$

$\upsilon_t \sim i.i.d.(0, \sigma^2)$

---

Instead of considering the alternative of just a stationary time series around a deterministic linear trend with time invariant parameters, he analyzes the following three possible alternative models:

***Alternative Hypotheses:***

---

Model(A) $y_t = \mu_1 + \beta_t t + (\mu_2 - \mu_1)DU_t + e_t,$

Model(B) $y = \mu + \beta_1 t + (\beta_2 - \beta_1)DT_t^* + e_t,$

Model(C) $y = \mu_1 + \beta_1 t + (\mu_2 - \mu_1)DU_t + (\beta_2 - \beta_1)DT_t + e_t,$

Where,

$DT_t^* = t - T_B$ and $DT_t = t$ if $t > T_B$ and 0 otherwise

Here, $T_B$ refers to the time of break, i.e., the period at which the change in the parameters of the trend function occurs. Model (A) describes what we shall refer to as the crash model. The null of a unit root is characterized by a dummy variable which takes the value one at the time of the break. Under the alternative we have a “trend-stationary” system. Model (A) allows for a one time change in the intercept of the trend function. Model (B) gives is what Perron calls the "changing growth" model. Under the alternative, we incorporate a change in the slope of the trend function, without a change in the level of the series at the time of the break. Under the null, the drift parameter changes from $\mu_1$ to $\mu_2$ at time $T_B$. Model (C) allows for both effects to take place simultaneously, i.e. a sudden change in the level followed by a different growth path.

Perron illustrates his point vividly when he uses some of the series of Nelson and Plosser (the nominal wages, quarterly real GNP and common stock prices), each one exhibiting a behavior that could be described by one of the alternative hypotheses models above (models A, B and C) and estimated a regression of the Dickey-Fuller type, i.e. :

$$y_t = \tilde{\mu} + \tilde{\beta}t + \tilde{a}y_{t-1} + \sum_{i=1}^{k} \tilde{c}_i \Delta y_{t-i} + \tilde{e}_t \qquad (1)$$

He finds that the estimated value of $a$ using the full sample for these series, is very close to 1, which leads to a small t-test and non-rejection of the unit root hypothesis. When he breaks the sample in two (for example pre-1929 and post-1929, accounting for a known break due to the crisis) he finds that the estimated $a$ falls dramatically, indicating that the series do not exhibit a unit root. However, due to the small samples available when the samples break in two parts, the t-statistics are not large enough still to reject the unit root hypothesis that $a = 1$, even at the 10 percent level. This experiment indicated that although the structural break (at 1929 for example) seems to be responsible for the near unit root of $a$, as splitting the sample indicates, the Dickey-Fuller tests on the split sample regressions are not powerful enough to reject the unit root hypothesis. A more powerful procedure is called for, so that based on the full sample would allow us to test consistently for a unit root, allowing the break to be exogenous.

It is highly important to note here the underlying assumption in the above models stating that the break date is exogenously given. Perron, uses an approach in the spirit of Box and Tiao (1975), which makes possible to separate outlying or aberrant events and model them as changes in the deterministic part of the general time series model, as opposed to assuming that these events are coming endogenously from the model process.

Here, thus, Perron assumes the time of changes in the trend function as fixed and given exogenously (say from previous study of the series, or some prior knowledge of events that alter the process) rather than as random variables to be estimated from the data.

To assess the effects of the presence of a shift in the level or a shift in the slope at a single point in time, on tests for the presence of a unit root, Perron first performed a Monte Carlo experiment. The experiment results show that if the magnitude of the shift is significant, one could hardly reject the unit root hypothesis even if the series is stationary with a broken trend and i.i.d. disturbances (thus, no unit root exists in the noise term). Perron extends the Dickey-Fuller testing strategy to ensure a consistent testing procedure against shifting trend function which is first to detrend the series and then analyze the behaviour of the estimated residuals.

Consider first detrending the raw series $\{y_i\}$ according to either model (A), (B) or (C). Let $\{\tilde{y}_i^{\,i}\}$, $i = A, B, C$, be the residuals from the regressions of $y_t$ on (1) $i = A$: a constant, a time trend and $DU_t$; (2) $i = B$: a constant, a time trend and $DT_t^*$; (3) $i = C$: a constant, a time trend, $DU_t$ and $DT_t$. Furthermore, let $\tilde{a}_i$ be the least squares estimator of $a$ in the following regression

$$\tilde{y}_i = \tilde{a}^i \tilde{y}_{t-1}^i + \tilde{e}_t \qquad (i = A, B, C; t = 1, 2, ..., T) \tag{2}$$

Perron derived the limiting distributions of the normalized least squares estimators $\tilde{a}^i$ and their *t*-statistics in from this regression (Theorem 2, Perron (1989)), which are functions of functional of Wiener processes and the parameter $\lambda = T_{\mathrm{B}} / T$, the ratio of the pre-break sample size to total sample size. He tabulated the percentage points of the limiting distributions for given values of $\lambda$. When $\lambda$ is either 0 or 1, the limiting distributions are identical over all models and the critical values are identical to those of Dickey and Fuller. When $\lambda$ is not equal to either 0 or 1 (and thus there is a structural break over the sample period), the critical values under the various models are noticeably smaller, (greater in absolute value) than the standard Dickey-Fuller critical values. Perron applied the modified Dickey-Fuller test for the same U.S. macroeconomic series used by Nelson and Plosser (1982) and found the strikingly different result that the unit root hypothesis can be rejected for all but three series: consumer price, velocity, and interest rate.

Perron employed an adjusted Dickey-Fuller (ADF) type unit-root testing strategy (see Dickey and Fuller 1981; Said and Dickey 1984). His test for a unit root in Models (A), (B), and (C) involve the following augmented regression equations:

$$y_t = \hat{\mu}^A + \hat{\theta}^A DU_t + \hat{\beta}^A t + \hat{d}^A D(TB)_t + \hat{a}^A y_{t-1} + \sum_{j=1}^{k} \hat{c}_j^A \Delta y_{t-j} + \hat{e}_t, \quad (1')$$

$$y_t = \hat{\mu}^B + \hat{\theta}^B DU_t + \hat{\beta}^B t + \hat{\gamma}^B DT_t^* + \hat{a}^B y_{t-1} + \sum_{j=1}^{k} \hat{c}_j^B \Delta y_{t-j} + \hat{e}_t \quad (2')$$

$$y_t = \hat{\mu}^C + \hat{\theta}^C DU_t + \hat{\beta}^C t + \hat{\gamma}^C DT_t^* + \hat{d}^C D(TB)_t \hat{a}^C y_{t-1} + \sum_{j=1}^{k} \hat{c}_j^C \Delta y_{t-j} + \hat{e}_t$$

$$DU_t(\hat{\lambda}) = 1 \quad (3')$$

$$t > T\lambda$$

Where, $DU_t(\hat{\lambda}) = 1$ if $t > T\lambda$ and zero otherwise.

The above equations' corresponding to models (A), (B), and (C) are constructed by nesting the corresponding models under the null and alternative hypotheses. The asymptotic distribution of the *t* statistics for $\hat{a}$ are the same as in (2). Perron's procedure is a conditional test given a known break point. This assumption of a known break date (treated as an exogenous event) raised the problem of pre-testing and data mining for the choice of the break date. After Perron (1989), the research focused on endogen zing the choice of a break point in testing procedures. We move on now in this research direction.

# Chapter 3

## 3.1 Unit Root Tests with Endogenous Determination of the Break Point

Zivot and Andrews (1992) influential paper addressed the issue of the exogenous determination of the break point used in Perron's ADF tests. The authors argue that since the choice of Perron's (1989) breakpoints are based on prior observation of the data, problems associated with "pre-testing" and data mining are an issue to his methodology. In contrast with Perron (1989), ZA (1992) use a data-dependent algorithm to proxy Perron's subjective procedure to determine the breakpoints. Such a procedure transforms Perron's unit root test, which is conditional on a known breakpoint, into an unconditional unit-root test. ZA (1992) develop a unit-root testing procedure that allows for an estimated break in the trend function under the alternative hypothesis. Furthermore, the authors, using their procedure, find less conclusive evidence against the unit root hypothesis than Peron (1989) found. Especially, the former using their asymptotic critical values cannot reject the unit-root hypothesis at the 5% level for 4 of the 10 Nelson and Plosser series for which Perron (1989) rejected the hypothesis. ZA (1992), take Perron's test statistic $t_{a^i}(\lambda)$ in a different manner. Perron's null hypothesis takes the break fraction $\lambda$ to be exogenous. The authors do not adopt an exogeneity assumption and instead they treat the structural break as an endogenous event. Their null hypothesis for the three models mentioned above is:

$$y_t = \mu + y_{t-1} + e_t \tag{6}$$

The authors use the null hypothesis that the series $\{y_t\}$ is integrated without a break and view the selection of the breakpoint λ for the dummy variables in Perron's regressions (1)-(3) as the outcome of an estimation procedure designed to fit $\{y_t\}$ to a certain trend-stationary representation; that is, we assume that the alternative hypothesis stipulates that $\{y_t\}$ can be represented by a trend-stationary process with a one-time break in the trend occurring at an unknown point in time. The goal is to estimate the breakpoint that gives the most weight to the trend-stationary alternative. The authors hope that their explicit algorithm for selecting the breakpoints for the series will be consistent with Perron's (subjective) selection procedure.

Summarizing, the authors test for a unit root against the alternative of stationarity with structural change at some unknown point.

Furthermore, the breaking point is chosen to give the least favorable result for the null hypothesis (6) using the test statistic (4). In other words, λ is chosen to minimize the one sided $t$-statistic for testing $a^i = 1$ $(i = A, B, C)$ when small values of the statistic lead to rejection of the null. Let $\lambda_{\inf}^{i}$ denote such a minimizing value for model *i*. Then, it follows that:

$$t_{\hat{a}^i}[\hat{\lambda}_{\inf}^{\iota}] = \inf_{\lambda \in \Lambda} t_{\hat{a}^i}(\lambda) \quad , \qquad \iota = A,B,C.$$

We should highlight that with the null model defined by (6) we no longer need the dummy variable $D(T_B)_t$ in (1) and (3).Following Perron's ADF strategy, Zivot and Andrews (1992), use the following regression equations to test for a unit root:

$$y_t = \hat{\mu}^A + \hat{\theta}^A DU(\hat{\lambda}) + \hat{\beta}^{\Lambda} t + \hat{a}^A y_{t-1} + \sum_{j=1}^{k} \hat{c}_j^A \Delta y_{t-j} + \hat{e}_t \quad (1')$$

$$y_t = \hat{\mu}^B + \hat{\beta}^B t + \hat{\gamma}^B DT_t^*(\hat{\lambda}) + \hat{a}^B y_{t-1} + \sum_{j=1}^{k} \hat{c}_j^B \Delta y_{t-j} + \hat{e}_t \quad (2')$$

$$y_t = \hat{\mu}^C + \hat{\theta}^C DU_t(\hat{\lambda}) + \hat{\beta}^C t + \hat{\gamma}^C DT_t^*(\hat{\lambda}) + \hat{a}^C y_{t-1} + \sum_{j=1}^{k} \hat{c}_j^C \Delta y_{t-j} + \hat{e}_t \quad (3')$$

Where, $DU_t(\hat{\lambda}) = 1$ if $t > T\lambda$ and zero otherwise Furthermore; $DT_t^*(\lambda) = t - T\lambda$ if $t > T\lambda$ and zero otherwise. Notice that the "hats"on λ parameters in (1')-(3') are employed to emphasize that that they correspond to estimated values of the break fraction. The authors determine the breaking points and the minimum t-statistics as follows: For each series, (1'), (2'), or (3') were estimated by ordinary least squares with the break fraction, $\lambda = T_B / T$ , ranging from $j = 2/T$ to $j = (T-1)/T$. (This range corresponds to our choice of A = [.001, .999]. In fact, the results are not sensitive to this particular choice of A.) For each value of A, the number of extra regressors, *k*, was determined using the same procedure as that of Perron, and the *t* statistic for testing $a_1 = 1$ was computed. The minimum *t* statistics reported are the minimums over all $T-2$ regressions, and the break years are the year's corresponding to the minimum *t* statistics.

As far as the breakpoint algorithm that the authors choose is concerned, it can be said that it is in generally consistent with the subjective selection procedure used by Perron for the Nelson and Plosser series and the postwar quarterly real GNP series. Especially, Zivot and Andrews (1992) find that the estimated break year (estimated with the method mentioned above) corresponds to the year of the great depression, 1929, for the eight series that Perron rejected the unit toot hypothesis. The three series with estimated breakpoints not consistent with Perron's choice are consumer prices, velocity, and the interest rate. We should notice that these are the series for which Perron does not reject the Unit root hypothesis. Additionally, for the postwar quarterly real GNP series, the minimizing breakpoint occurs in the second quarter of 1972. Perron's choice of 1973:I produces the fifth smallest *t* statistic, but the numerical difference between the *t* statistics for these two dates, however, is very small.

## 3.2 Evidence that Perron's unit root test is biased

One of the most important results of ZA (1992) paper is that Perron's unit root test is biased. The authors provide evidence that when we treat the selection of $\lambda$ as the outcome of an estimation procedure, we can no longer use Perron's critical values to test the unit-root hypothesis. With the minimum t-statistics estimation of the break point they propose, their interpretation of Perron's unit root test is: Reject the null of the unit root if

$$\inf_{\lambda\in\Lambda} t_{\hat{a}^i}(\lambda) < \kappa^i_{\inf,a}, \qquad i = A,B,C \tag{8}$$

Where $\kappa^i_{\inf,a}$ denotes the size/significance level-$\alpha$ left-tail critical value from the asymptotic distribution of $\inf_{\lambda\in\Lambda} t_{\hat{a}^i}(\lambda)^i$. By definition, the left-tail critical values in (8) are at least as large in absolute value as those computed for an arbitrary fixed $\lambda$ (i.e., these of

Perron).The above statement says that the critical values that Perron uses are too small (in absolute values) and therefore, Perron's unit-root tests are biased toward rejecting the unit-root null hypothesis. Critical values of the asymptotic distribution of $\inf_{\lambda \in \Lambda} t_{\hat{a}^i}(\lambda)^i$ are obtained by simulation methods. As expected, for a given size of a left-tailed test, the critical values for $\inf_{\lambda \in \Lambda} t_{\hat{a}^i}(\lambda)^i$ are more negative than the critical values obtained by Perron for any fixed value of the break fraction $\lambda$. The biggest difference occurs for the Model (A) densities. At the 5% level, the critical value for $\inf_{\lambda \in \Lambda} t_{\hat{a}^i}(\lambda)^i$ is -4.80 and the average value, over $\lambda$, of Perron's critical values is - 3.74. Thus, at the 5% level, their critical value is roughly 24% larger (in absolute value) than Perron's.

Concluding, the authors transform Perron's unit root test (which is conditional on structural change at a known point in time) by endogenizing the estimation procedure of the break points. Their analysis is motivated by the fact that the breakpoints used by Perron are data dependent. The authors find less conclusive evidence against the unit root hypothesis than Perron found for many series. Especially, they reverse Perron's conclusions for 5 of 11 Nelson and Plosser series for which the latter rejected the unit root hypothesis at a 5% significance level. Moreover, they reverse his unit-root rejection for the postwar quarterly real-GNP series. The authors highlight that their results do not indicate an acceptance of the unit root hypothesis, but provide evidence that the results of Perron's are less conclusive against the unit root hypothesis. Finally, for the three remaining series of Nelson and Plosser namely industrial production, nominal GNP, and real GNP they provide stronger evidence against the rejection of the unit-root hypothesis than that given by Perron.

# Chapter 4

## 4.1 Incorrect Break Point Estimation and Endogenous unit root tests

The pioneering work of Perron (1989) described in section 1, illustrates the importance of including a structural break in unit root tests. Perron showed that a bias exists against rejecting the null of unit root hypothesis when the time series data are actually produced form a stationary model which is stationary around a structural break. Andrews and Zivot (1992), as we described in section 2, improved upon Perron's tests by challenging one of Perron's main underlying assumptions, namely that the break point is known *a priori,* and adopted a procedure to endogenously determine the break point from the data. The *minimum test* suggested by Zivot and Andrews selects the break point to be the one that is the *least* favorable to the null of unit root, or in other words, where the *t*-statistic for a unit root is minimized. Perron (1997) suggested an additional endogenous break unit root test where the *t*-statistic is of the break coefficient is maximized in absolute values.

The above literature falls in the category of the *endogenous break unit root tests*. In this section, we seek to further assess the performance of these tests when the break point is estimated. No doubt the goal of endogenous break unit root tests is to estimate the break point correctly for inference in unit root tests. It is natural that how well this structural break can be estimated will have an impact on the inference of the unit root test. The work of Lee and Stravicich (2001) addressed this issue and examined the impact of estimating the break point on the aforementioned test of ZA (1992) and Perron (1997).

Nunes, Newbold and Kuan had already observed before Lee and Strazicich (2001) that spurious rejections of the unit root null can occur as the magnitude of the structural break increases under the null. Lee and Strazicich demonstrate that the endogenous break tests of ZA and Perron actually estimate the break point incorrectly and this is what produces the spurious rejections of the null. As already demonstrated Perron considers three models (A,B and C) of which Lee and Strazicich used A and C. The null models used are therefore:

Model (A): $y_t = \mu_0 + d_1 B_t + y_{t-1} + \upsilon_t,$

Model (C): $y_t = \mu_0 + d_1 + B_t + d_2 D_t + y_{t-1} + \upsilon_t,$

where $B_t = 1$ for $t = T_B + 1$ and zero otherwise, $D_t = 1$ for $t \geq T_B + 1$ and zero otherwise

Let $\lambda$ be the parameter denoting the fraction of time periods before the break, such that $T_B / T \to \lambda$ as $T \to \infty$. The test regressions are described as follows:

Model (A): $y_t = a_0 + a_1 t + a_2 B_t + a_3 D_t + \beta y_{t-1} + \sum_{j=1}^{k} c_j \Delta Y_{t-j} + e_t$

Model (C): $y_t = a_0 + a_1 t + a_2 B_t + a_3 D_t + a_4 DT_t + \beta y_{t-1} + \sum_{j=1}^{k} c_j \Delta Y_{t-j} + e_t$

where $DT_t = t$ for $t \geq T_B + 1$ and zero otherwise.

Under the null $\beta = 1$ and the test statistic is the *t*-statistic testing this hypothesis.

ZA and Perron (1997) derive their critical values while assuming $d_1 = 0$ for Model (A) and $d_1 = d_2 = 0$ for model (C), under the null. Lee and Strazicich (2001) demonstrate by Monte-Carlo simulations that *the critical values of these endogenous break tests increase in accordance with the magnitude of the break under the null. Thus, in the presence of a structural break under the null, using the critical values ZA and Perron (1997) will lead to spurious rejections*, which increase significantly with the magnitude of the break. We elaborate a bit on the methodology and the results they derive in what follows.

The authors performed simulations to produce random samples from the null models described above with $T = 100$, with 5,000 replications and the break point at $T_B = 50$ and using five different magnitudes ranging from 0 to 10. They perform the endogenous tests utilizing both the sets of critical values by Perron (1997) and ZA (1992) for 5 percent significance level. Their findings are summarized as follows. First *Both Perron and ZA tests lead to increasing spurious rejections as the magnitude of the break increases*. Second, both tests *tend to determine the break point incorrectly at* $T_B - 1$ *instead of* $T_B$ *and even more so as the magnitude of the break increases.*

But what is the effect of the incorrect estimation of the break point? In short, when using the incorrect break point, all estimators, including the unit root *t*-test statistic and $\beta$ (coefficient of $y_{t-1}$ in the regression equations above) become biased, and the bias in estimating $\beta$ is *maximized* at $T_B - 1$. As a result, the unit root *t*-test is statistic approaches its minimum at the incorrect break point $T_B - 1$. These results suggest a direct relation between incorrect estimation of the break point and spurious rejections of the null. The effect of using the incorrect break-point on the estimation of $\beta$ is thus reflected on the fact that on the simulations by Lee and Strazicich at all break magnitudes the bias is maximized at period $T_B - 1$.

What is more, the authors perform the same simulations under the alternatives (with $\beta = 0.8$) and find that the results are similar to those under the null. Assuming the break point most frequently estimated by the ZA and Perron (1997) tests, namely $T_B - 1$, again leads to maximum bias of in estimating $\beta$. Thus, the same problem of dependency of the test statistic on biased parameter estimates occurs under the alternative. Although the test statistic under the alternative appears to have high power, to reject the unit root null, this is exaggerated by the estimation bias of $\beta$ and the resulting size distortions.

# Chapter 5

## 5.1 Minimum LM Unit Root Test with One structural Break

On the above sections we established that allowing for structural breaks in unit root tests in important in developing consistent testing procedures for the presence of a unit root. Whereas the pioneering work of Perron assumed the break point being known *a priori*, or exogenously given, subsequent developments allowed for an endogenous determination of the break point. Zivot and Andrews (1992) suggested adopting a minimum statistic that determines the break point where the unit root t-test is minimized (i.e. the most negative). Perron (1997) and Vogelsang and Perron (1994) suggest selecting the break by examining the significance of the dummy variables in the testing regression that capture the structural break. These procedures are referred to as *endogenous break unit root tests.*

The above augmented Dickey-Fuller (ADF) type endogenous break unit root tests omit, as we have seen, the possibility of a unit root with break. If a break exists under the unit root null, two undesirable results can follow. The endogenous break unit root tests will exhibit size distortions such that the unit root null is over-rejected. When utilizing such tests, a false conclusion that a series is trend stationary with a break is reached when in fact the series is stationary with a break. As such, spurious rejections can occur, and even more so when the magnitude of the break increases. See the analysis in section 3 for a description of this problem. This nuisance parameters problem is restricted to the endogenous break unit root tests. Notably, the exogenous break unit root test procedure of Perron does not depend on the magnitude of the break, even when a break occurs under the null. Thus there is no size distortion in the exogenous break test, even when the magnitude of the break is large. Moreover, the endogenous tests *estimate the break point incorrectly*. Lee and Strazicich (2001) note that these tests tend to identify the break point one period prior to the true break point, that is at $T_B - 1$ instead of $T_B$. The bias in estimating the persistence parameter is maximized at this break point and spurious rejections are most likely to occur. The problem pertains under both the null and the alternative hypothesis.

Lee and Strazicich (2004) propose an alternative one-break unit root test that does not lead to the above problems. They utilize the theoretical findings presented in Lee and Strazicich (2003), who propose an endogenous two-break Lagrange Multiplier (LM) unit root test that is unaffected by structural breaks under the null. Similar to the two-break LM test, the one-break test proposed is invariant to the magnitude of a structural break under the null and alternative hypotheses. Thus, spurious rejections will not occur in either case. Therefore, by combining the two-break unit root test of Lee and Strazicich (2003) with the one-break test, researchers can more accurately determine the correct number of breaks.

We describe now the testing procedure of Lee and Strazicich (2004). Consider (similarly to Schmidt and Philips P.C.B (1992) ) the following data D.G.P. based on the unobserved components model:

$$y_t = \delta' Z_t + X_t, \quad \mathrm{X}_t = \beta \mathrm{X}_{t-1} + \varepsilon_t \qquad (4.1)$$

Where $Z_t$ contains exogenous variables. The unit root null hypothesis is described by $\beta = 1$. If $Z_t = [1, t]'$ then the D.G.P. is the same as that shown in the no break LM unit roor test of Schmidt and Philips (1992, hereafter SP). We consider two models of structural change. "Model A" is known as the "crash" model, and allows for a one-time change in intercept under the alternative hypothesis. Model A can be described by $Z_t = [1, t, D_t]'$, where $D_t = 1$ for $t \geq T_B + 1$ and zero otherwise, $T_B$ is the time of the break and $\delta = (\delta_1, \delta_2, \delta_3)$. Model C allows for a shift in intercept and change in trend slope under the alternative hypothesis and can be described by $Z_t = [1, t, D_t, DT_t]'$, where $DT_t = t - T_B$ for $t \geq T_B + 1$ and zero otherwise.

According to the LM (score) principle, unit root test statistics are obtained from the following regression:

$$\Delta y_t = \delta' \Delta Z_t + \varphi \tilde{S}_{t-1} + u_t \qquad (4.2)$$

*Where* $\tilde{S} = y_t - \tilde{\psi}_x - Z_t \tilde{\delta}, t = 2, ..., T$ ; $\tilde{\delta}$ are the coefficients in the regression of $\Delta y_t$ on $\Delta Z_t$;

$\tilde{S} = y_t - \tilde{\psi}_x - Z_t \tilde{\delta}, t = 2, ..., T$; $\tilde{\delta}$ are the coefficients in the regression of $\Delta y_t$ on $\Delta Z_t$;

and $\tilde{\psi}_x$ is the restricted MLE of $\psi_\chi$ given by $y_1 - Z_1 \tilde{\delta}$. Note that the testing regression (4.2) involves $\Delta Z_t$ instead of $Z_t$. Therefore, $\Delta Z_t$ is described by $[1, B_t]'$ in model A and $[1, B_t, D_t]'$ in model C, where $B_t = \Delta D_t$ and $D_t = \Delta DT_t$. Thus $B_t$ and $D_t$ correspond to a change in intercept and trend under the alternative, and to a one period jump and (permanent) change in drift under the null hypothesis, respectively. The unit root null hypothesis is described by $\varphi = 0$ and the LM *t-test* statistic is given by:

$$\tilde{\tau} = t - statistic \text{ testing the null hypothesis } \varphi = 0. \qquad (4.3)$$

To correct for auto correlated errors, we include augmented terms $\Delta\tilde{S}_{t-j,}\ j=1,...,k$ in (4.1) as in the standard ADF test. The location of the break ( $T_B$ ) is determined by searching all possible break points for minimum (i.e. the most negative) unit root *t-test* statistic as follows:

$Inf\,\tilde{\tau}(\tilde{\lambda}) = Inf\,\tilde{\tau}(\lambda)$, Where $\lambda = \mathrm{T}/\mathrm{T_B}$. Below on table (1) are the critical values of the test.

**Table 1. Critical Values of the One-Break Minimum $LM_\tau$ Test**

**Model A**

| 1% | 5% | 10% |
|---|---|---|
| -4.239 | -3.566 | -3.211 |

**Model C**

| λ | 1% | 5% | 10% |
|---|---|---|---|
| .1 | -5.11 | -4.50 | -4.21 |
| .2 | -5.07 | -4.47 | -4.20 |
| .3 | -5.15 | -4.45 | -4.18 |
| .4 | –5.05 | -4.50 | -4.18 |
| .5 | -5.11 | -4.51 | -4.17 |

Note: All critical values were derived in samples of size T = 100. Critical values in Model C (intercept and trend break) depend (somewhat) on the location of the break ($\lambda = T_B/T$) and are symmetric around λ and (1-λ). Model C critical values at additional break locations can be interpolated.

## 5.2 The two-Break minimum LM Unit Root Test

In many time series allowing for one structural break may be very restrictive. If we apply a unit root test that allows for more than one structural breaks then this procedure could lead to greater probability to reject a false null hypothesis[1] (greater power to reject the null). Given that recent research indicates that many economic series may have more than one structural brakes, there is a need to allow for more than one structural brakes when we test for a unit root. Lumsdaine and Papell, (1997) make a contribution in this direction by extending the ZA test to two structural breaks. A potential weakness of these minimum unit root test is that they assume no structural breaks under the null and derive their critical values under these assumptions. Therefore, it is straightforward that a rejection of the null hypothesis would not necessary reject the unit root but instead would imply rejection of the unit root without break.

Therefore, both for unit root tests with exogenous and endogenously determined structural break if the null hypothesis does not contain structural breaks then the test statistic will diverge under the null as the size of the breaks increases. Especially, in the case of minimum endogenous tests, Nunes et al. (1997) and Lee et al. (1998) provide evidence that assuming no structural break under the null in the ZA test makes the associated test statistic diverge and leads to spurious rejections when the time series under examination contains structural brakes.

Lee and Strazicich (2003), suggest a solution to the problems of bias and spurious rejections they found using the two break LP unit root test. In order to do so, they propose a minimum two break LM test. This test is based on the Lagrange Multiplier (LM) unit root test suggested by Schmidt and Phillips (1992). In contrast with the Lumsdaine and Papell, (1997) two break unit root test, the two break minimum LM unit root test has several advantages: (1) does not diverge as the breaks under the null increase in size, and is free of bias and spurious rejections, (2) there is no need to exclude structural breaks under the null (in contrast with the case of and Papell, (1997) two break unit root test), (3) is robust to misspecifications of the number of structural breaks under the null.

[1] The **power** of a statistical test is the probability that the test will reject a false null hypothesis (i.e. that it will not make a Type II error).

Recall that we have already described the three structural brake models considered by Perron. In contrast with Perron, Lee and Strazicich (2003) propose the following data generating process:

$$y_t = \delta' Z_t + e_t , \qquad e_t = \beta e_{t-1} + \varepsilon_t$$

Where $Z_t$ is a vector of exogenous variables and $\varepsilon_t \sim iid(0,\sigma^2)$. We should highlight that two structural breaks can be considered form the above DGP. The authors examine only models A and C as they describe most economic time series. The structural brakes can be considered as follows**: model A allows for two shifts in the level** and is described by defining $Z_\tau = [1, t, D_{1t}, D_{2t}]'$, where $D_{jt} = 1$ for $t \geq T_{Bj} + 1,\quad j = 1,2$ and zero otherwise. Notice that $T_{Bj}$ denotes the time period when the break occurs. Moreover, **model C includes two changes in level and trend** and is described by defining $Z_t = [1, t, D_{1t}, D_{2t}, DT_{1t}, DT_{2t}]'$, where $DT_{jt} = t$ for $t \geq T_{Bj} + 1$, $j = 1,2$ and zero otherwise.

Important contribution of this paper is that both under the null and the alternative the DGP includes breaks in a consistent manner. Especially, for model A, depending on the value of β, we have:

$$y_t = \mu_0 + d_1 B_{1t} + d_2 B_{2t} + y_{t-1} + v_{1t} \qquad (5.1)$$

$$y_t = \mu_1 + \gamma t + d_1 D_{1t} + d_2 D_{2t} + v_{2t} \qquad (5.2)$$

Where $v_{1t}$ and $v_{2t}$ are stationary error terms, $B_{jt} = 1$ for $t = T_{Bj} + 1$, $j = 1,2$ and zero otherwise, and $d = (d_1, d_2)'$. Note that in model C, $D_{jt}$ terms are added in (5.1) and $DT_{jt}$ terms to (5.2) respectively. It should be emphasized that according to Perron (1989) the inclusion of $B_{jt}$ in equation (5.1) above is necessary to ensure that the asymptotic distribution of the test statistic is invariant to the size of the breaks (d) under the null[2].

The two-break LM unit root test statistic can be estimated by regression according to the LM (score) principle as follows:

$$\Delta y_t = \delta' \Delta Z_t + \Phi \tilde{S}_{t-1} + u \qquad (5.3)$$

where $\tilde{S}_t = y_t - \tilde{\psi}_\chi - Z_\tau \tilde{\delta}$, $t = 2,...T$, $\tilde{\delta}$ are coefficients in the regression of $\Delta y_t$ on $\Delta Z_t$, $\tilde{\psi}_\chi$ is the restricted MLE of $\psi_\chi (\psi + \mathrm{X}_0)$ given by $y_1 - Z_1 \tilde{\delta}$ and $y_1$ and $Z_1$ are the first observations of $y_t$ and $Z_t$ respectively. It follows that the unit root null hypothesis is described by $\Phi = 0$ and the LM tests statistics are given by:

$\tilde{\rho} = \mathrm{T}\tilde{\Phi}$

$\tilde{\tau} = t$ -statistic testing the null hypothesis $\Phi = 0$.

Notice that under appropriate conditions and under the null the asymptotic distribution of $\tilde{\rho}$ and $\tilde{\tau}$ respectively are given by equation (6a) and (6b) in Lee and Strazicich (1999). Moving on to the determination of the breaks, the two-break minimum LM unit root test determines the break points $(TB_j)$ endogenously by utilizing a grid search as follows:

$$LM_\rho = \inf_\lambda \tilde{\rho}(\lambda)$$

$$LM_\tau = \inf_\lambda \tilde{\tau}(\lambda)$$

and the break point are determined to be where the test statistic is minimized. The asymptotic distribution of the endogenous two-break LM unit root tests can be described by equations (7a) and (7b) in Lee and Strazicich (1999).

[2] Recall that in Lumsdaine and Papell (1997) there are no structural breaks under the null.

Concluding, the authors find stronger rejections of the null using the Lumsdaine and Papell, (1997) test than with the LM test. Especially, at 5% significance level, the null is rejected for six series with the former test and four series with the LM test. Finally, according to the authors, using the two break minimum LM unit root test, rejection of the null hypothesis implies trend-stationarity.

# Chapter 6

## 6.1 Empirical Results

In this paper we study five equity markets, namely those of France, Athens, London, Germany and New York.

**Table 2.**

| Country | Index | |
|---|---|---|
| **USA** | DJ | Dow Jones |
| **FRANCE** | CAC | France Cac 40 |
| **GERMANY** | DAX | Dax 30 Performance |
| **ENGLAND** | FTSE | FTSE-100 |
| **GREECE** | GEN | Athens General |

*Stock Exchanges and Stock Indices under Investigation

We apply the methodologies above for the five time series regarding Stock Exchange price indices. Specifically, our data consist of monthly observations over a period from January 1993 to December 2009. Our data source is Eurostat. First we seek to test for the presence of a unit root with one structural break. We test using both Model A and Model C using the GAUSS codes for the one structural break Minimum LM test of Lee and Strazicich (2004). As we have already seen above in the description of the min LM test, Model (A) allows for a one time structural change in the level of the series (under the null of unit root) or a one time permanent change on the intercept of the trend stationary time series model (under the alternative). This corresponds to the "crash" model of Perron. Model (C), on the other hand allows for both a one time change in the intercept (or in the level under the null) and a change in the growth rate (or the drift parameter under the null). The test regression is our (4.2) equation which we write again here:

$$\Delta y_t = \delta ' \Delta Z_t + \varphi \tilde{S}_{t-1} + u_t \qquad (4.2)$$

And the test statistic for a unit root is

$\tilde{\tau} = t - statistic$ testing the null hypothesis $\varphi = 0.$ (4.3)

For which critical values are given in Table (1). The results are given in the following table 3

| Index | Model | min LM test | critical value | Break Time |
|---|---|---|---|---|
| **DAI** | **A** | -2,9122 | -3,57 | 116 (08 2002) |
| | **C** | -3,2193 | -4,45 | 60 (12 1997) |
| **ASEI** | **A** | -3,0294 | -3,57 | 92 (08 2000) |
| | **C** | -3,6728 | -4,45 | 68 (08 1998) |
| **CAC40** | **A** | -3,1982 | -3,57 | 105 (09 2001) |
| | **C** | -4,1893 | -4,45 | 68 (09 1998) |
| **FTSE** | **A** | -2,5833 | -3,57 | 114 (06 2002) |
| | **C** | -3,1515 | -4,45 | 67 (07 1998) |
| **DOW** | **A** | -2,7127 | -3,57 | 183 (03 2008) |
| | **C** | -4,1468 | -4,45 | 59 (11 1997) |

**Table 3:** One structural Break Unit Root test of Lee and Strazicich (2004) for the five Stock Price Indices from Jan. 1993 to Dec. 2009. Critical values are at 5% level.

These results clearly show that when we allow for a structural break under both the null and alternative, the null hypothesis of Unit root for all the five series cannot be rejected, therefore we *conclude the existence of a unit root* and a structural break in the form of either Model (A) or Model (C). The non-rejection of the null of a unit root is strong across all tests as the respective Minimum t-statistics of Lee and Strazicich are well in the acceptance area, given the critical values above. We can say that when Model C is used, the time of the structural break is uniformly estimated well before the respective break time estimated from using Model (A).

Moving on, we will test for the presence of unit root with two structural breaks. In order to do so, we apply the two break minimum LM unit root test (discussed in section 5) in the five series described above. As we did above, we are interested in models A and C. Recall that model (A) allows for two shifts in the level (the shifts are for one period under the null and permanent otherwise, see equations (5.1) and (5.2) respectively) and model (C) allows for two changes in the level and trend. Using the Gauss code provided by [3]Junsoo Lee (updated 03/2005) we obtain the break points and tests statistics shown in table 4 below.

| Index | Model | min LM test | critical value | Break Time one | Break Time two |
|---|---|---|---|---|---|
| **DAI** | **A** | **-2,3851** | **-5,67** | **88 (04/2000)** | **104 (08/2001)** |
| | **C** | **-3,1161** | **5,71** | **81 (09/1999)** | **119 (11/2002)** |
| **ASEI** | **A** | **-2,4298** | **-5,67** | **84 (12/1999)** | **92 (08/2000)** |
| | **C** | **-3,1106** | -5,65 | **92 (08/2000)** | **162 (06/2006)** |
| **CAC40** | **A** | **-2,2540** | **-5,74** | **70 (10/1998)** | **96 (12/2000)** |
| | **C** | **-2,9763** | **-5,74** | **70 (10/1998)** | **118 (10/2002)** |
| **FTSE** | **A** | **-1,9866** | **-5,67** | **70 (10/1998)** | **104 (08/2001)** |
| | **C** | **-2,7692** | **-5,67** | **70 (10/1998)** | **118 (10/2002)** |
| **DOW** | **A** | **-2,2619** | **-5,67** | **70 (10/1998)** | **121 (01/2003)** |
| | **C** | **-3,4240** | **-5,73** | **98 (02/2001)** | **179 (11/2007)** |

**Table 4:** Two structural breaks minimum LM unit root test of Lee and Strazicich (2003), for the five Stock Price Indices from Jan. 1993 to Dec. 2009. Critical values are at 5% level.

[3] The statistic $LM_{¿}$ has been computed by using a Gauss program provided by Junsoo Lee via the web page http://www.cba.ua.edu/»jlee/gauss.

In this case, two structural breaks are considered (both under the null and the alternative). Comparing the LM statistics seen above with the appropriate critical values for each series, *we can conclude that we cannot reject the null hypothesis of unit root with two breaks for all the five series under consideration* (again the test statistics are two small in absolute values to reject the null). These results are consistent for both models A and C.

## 6.2 One vs. Two structural breaks

A natural question arises from all the above: Why use two structural breaks instead of just one, and even more, when are we to prefer the one or the other specification? The answer given by the literature is that allowing for multiple structural breaks is better. Several studies argue that only considering one endogenous break is insufficient and leads to a loss of information when actually more than one break exists (Lumsdaine and Papell (1997)). Lumsdaine and Papell (1997) introduce a procedure to capture two structural breaks and argue that unit roots tests that account for two significant structural breaks are more powerful that those that allow for a single break. Lumsdaine and Papell extend the ZA (1992) model allowing for two structural breaks under the alternative hypothesis of the unit root test and additionally allow for breaks in level and trend. Ben-David et al (2003) argue that failure to allow for multiple breaks can cause the non-rejection of the unit root null by these tests which incorporate only one break. Maddala and Kim (2003) believe that allowing for the possibility of two endogenous break points provides further evidence against the unit root hypothesis. Ohara (1999) utilizes an approach based on sequential t-tests of ZA to examine the case on m breaks with unknown break dates. He provides evidence that unit root tests with multiple trend breaks are necessary for both asymptotic theory and empirical applications.

As Ben David at al. put it, models that allow just one structural break face a tradeoff. Studies which use long-term data, such as Ben-David and Papell (1995), cannot determine if, and when breaks occur after a large significant event (like a War or a big Recession) because the breaks are dominated by these great events. On the other hand, studies which use more concurrent data, as in Ben-David and Papell (1998), are unable to gauge the magnitude of these slowdowns from a long-run perspective. Ben-David et al (2003) examine the unit root hypothesis for growth rates of a multitude of countries, allowing for multiple structural breaks. They reject the unit root hypothesis for three quarters of the countries – approximately 50% more rejections than in models that allow for only one break, which demonstrates the fact that restriction to only one break can cause non-rejection of the null.

# Chapter 7

## 7.1 Crisis in the global Economy

Continuing our analysis we will examine what was happened exactly in the years when the breaks appeared. We focus on financial crisis of 1997, 2002, 2007. The financial crisis of 1997 in East Asia has had a major impact on conventional thinking regarding the world economy. Prior to the crisis the East Asia economies were viewed as paragons of the virtue of the free market that increasingly set the standards across the globe.

Any crisis in capitalisms also affects these with capital on savings are eroded, Stock markets plumped, property values full and currencies are devaluated. The 1997 crisis should not be a momentous shock for Marxists as it was for mainstream commentators. Seen crises were endemic to the capitalist system and accord well with the boom and bust cycle.

The highly integrated nature of the world markets and open markets has meant that weaker economies have become especially vulnerable. The shock waves of East Asia did spread around the globe, but they were felt mostly keenly in “less developed” areas.

However what the East Asian experience also shows is that even relatively strong economies are by no means immune from shocks occurring nearby countries. And extending the logic there are no guarantee that crises can be completely sealed off even from the heartlands. At least we can conclude that the west had a close shave after 1997.

In the after math of the East Asian crisis a backlash against globalization has developed one that received a major boost with the collapse of the Multilateral Agreement o Investment in 1998, the failure of the two talks in Seattle in November 1999, mass protests against IMF and World Bank in Prague in September 2000 and the largest demonstration the 300.000 strong march against the G8 in Geneva in July 2001. Yet given that it has been the recent strength of the US economy that has greatly assisted the East Asian recovery this does not bode well for the rulers of East Asia give the stagnation of the US economy in 2001.

The stock market downturn of 2001 some say “stock market crash” or “the Internet bubble bursting” in the sharp drop in stock prices during 2002 in stock exchanges across US and Europe. Indices slid steadily starting in March 2002 with dramatic declines in July and September leading to lows last reached in 1997 and 1998. The dollar declines steadily against the euro reaching 1 to 1 valuation not seen since the euro’s introduction.

This downturn can be viewed as part of a larger bear market or correction, after dead-long bull market had led to unusually high stock valuations. In fact some Internet comparers went bankrupt and other went down dramatically in value. The IMF had expressed concern about instability in US stock market in the months leading up to the sharp downturn.

To put the downturn of 2002 in perspective here is a look at annual US stock market decline in 2000, 2001 and 2002.

- Down Jones Industrial Average

In 2000, the Dow lost 6, 17% of its value [11.497, 10 to 10.788, 00]

In 2001 the Dow lost 5, 35% of its value [10.788, 00 to 10.021, 60]

In 2002 the Dow lost 16, 76% of its value [10.021, 60 to 8.341, 63]

Finally the global financial crisis in 2007 affected on the stock markets around the world. The effects really started in the middle of 2007 and into 2008. Around the world stock markets have fallen large financial institutions have collapsed and government in even the wealthiest nations have had to come up with rescue package to bail out their financial systems. A financial crisis developed with remarkable speed starting in the summer of 2008 as mortgage-related securities that had spread through the US and global financial system suddenly collapsed in value. In the US the signs of s systemic crisis were easy to see, in recent economy, political and ideological developments. Output and employment in the US was falling with a speed not seen in many decades. With loan losses mounting and the fall of Lehman Brothers on September 15, 2008, panic broke out on the inter-bank loan market. There had been a rapid slowdown in North America and European Economies. On 30th September the UK revealed that it had zero growth for the past quarter. Along with Germany it should officially be in recession by the end of 2008.

## 7.2 Conclusions

The method of estimation of the standard regression model, Ordinary Least Square (OLS) method, is based on the assumption that the means and variances of these variables being tested are constant over the time. Incorporating non-stationary or unit root variables in estimating the regression equations using OLS method give misleading inferences. The testing of the unit roots of a series is a precondition to the existence of cointegration relationship, originally, the Augmented Dickey-Fuller (1979) test was widely used to test for stationarity. Perron (1989) showed that failure to allow for an existing break leads to a bias that reduces the ability to reject a false unit root null hypothesis. Perron proposed allowing for a known or exogenous structural break in the Augmented Dickey-Fuller (ADF) tests to overcome this problem. Zivot and Andrews (1992) and Perron (1997) proposed determining the break point 'endogenously' from the data. Lumsdaine and Papell(1997) extended the Zivot and Andrews (1992) model to accommodate two structural breaks. Lee and Strazicich (2003) propose a two break minimum Lagrange

Multiplier (LM) unit root test in which the alternative hypothesis unambiguously implies the series is trend stationary.Our overall findings suggest that the null hypothesis of unit root with one or two structural breaks cannot be rejected. This result may be of interest to academic researchers and practitioners who are willing to expand the theory by using co integration and common trends analysis to study the co movements of five stock markets indices. Co integration and the existence of common trends imply that in the long run any benefits from portfolio diversification are diminished. It is important to emphasize that we utilize a LM unit root test that endogenously determines two structural breaks in level and trend. By allowing for two structural breaks in each country, our tests benefit from greater ability to reject a false unit root null.

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## Uniform Resource Locator (URL)

http://www.tradingeconomics.com/

www.**stata**.com/**stata10**/

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# Appendix I

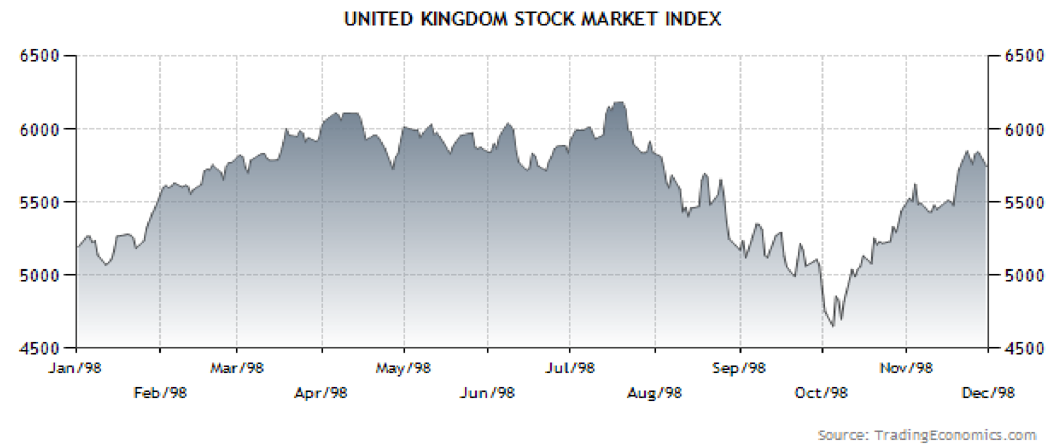
Below we present historical data and news for the above 5 stock markets. From 1987 until 2011 the ASE market value averaged 2021.06 points reaching an historical high of 6355.04 points in September of 1999 and a record low of 97.36 points in January of 1987. This page includes: Greece Stock Market Index chart, historical data and news.



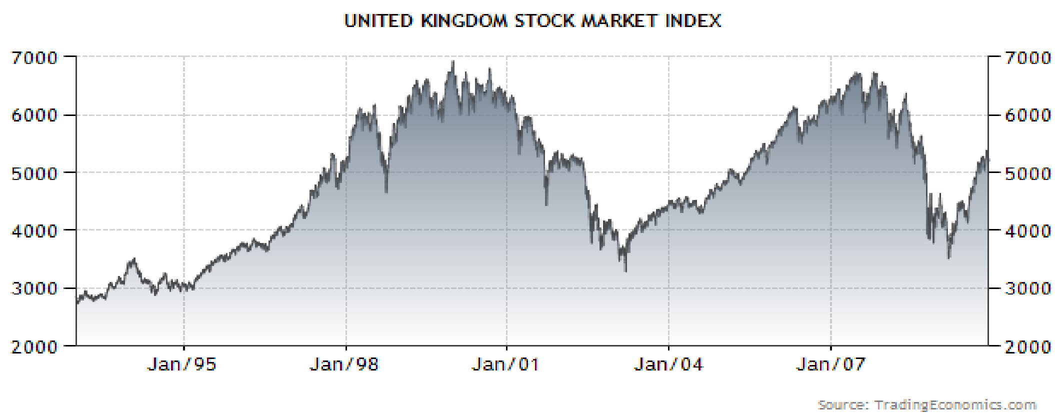
From 1970 until 2011 the DAX market value averaged 2508.71 points reaching an historical high of 8105.69 points in July of 2007 and a record low of 372.30 points in November of 1974. This page includes: Germany Stock Market Index chart, historical data and news.



From 1984 until 2011 the FTSE 100 market value averaged 3870.98 points reaching an historical high of 6930.20 points in December of 1999 and a record low of 986.90 points in July of 1984. This page includes: United Kingdom Stock Market Index chart, historical data and news.

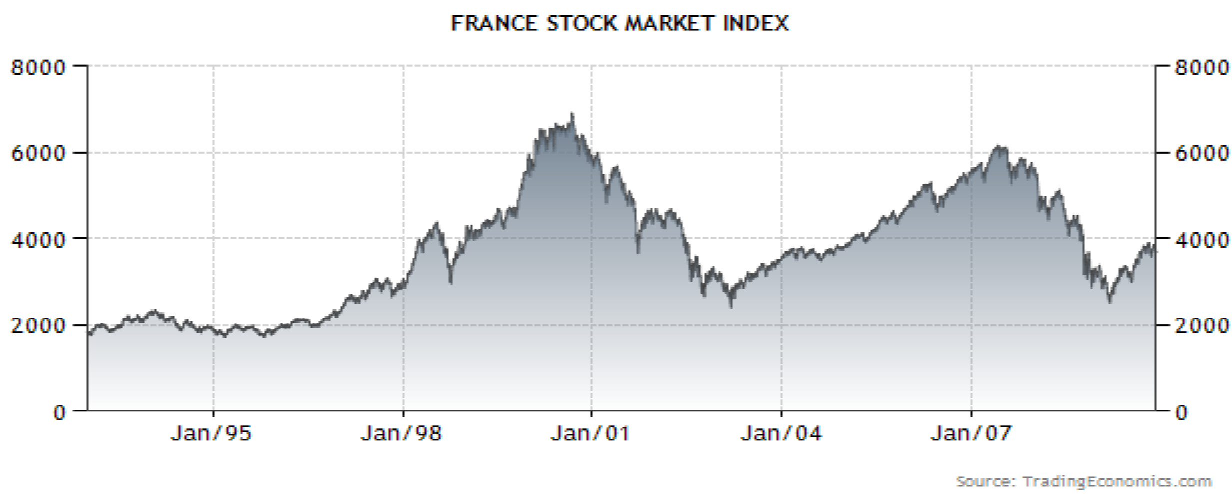




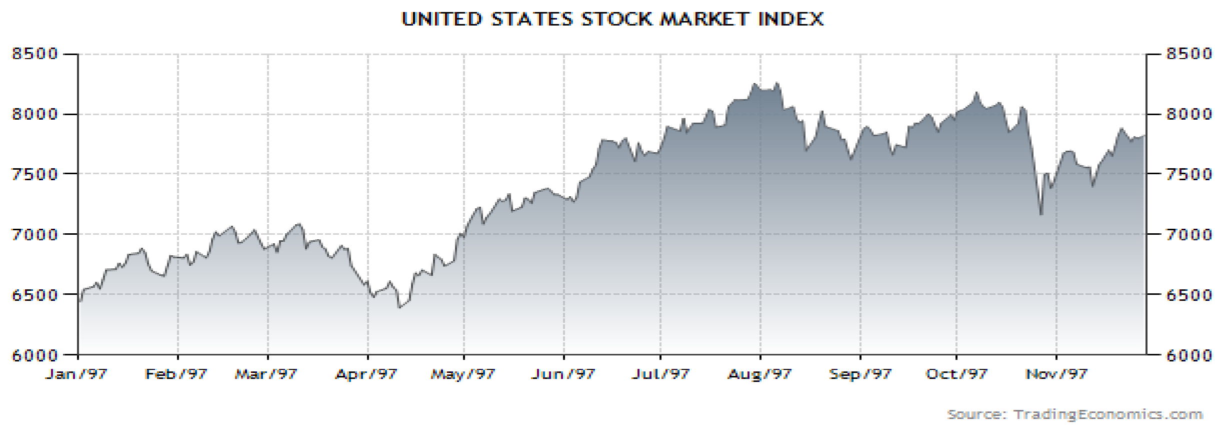


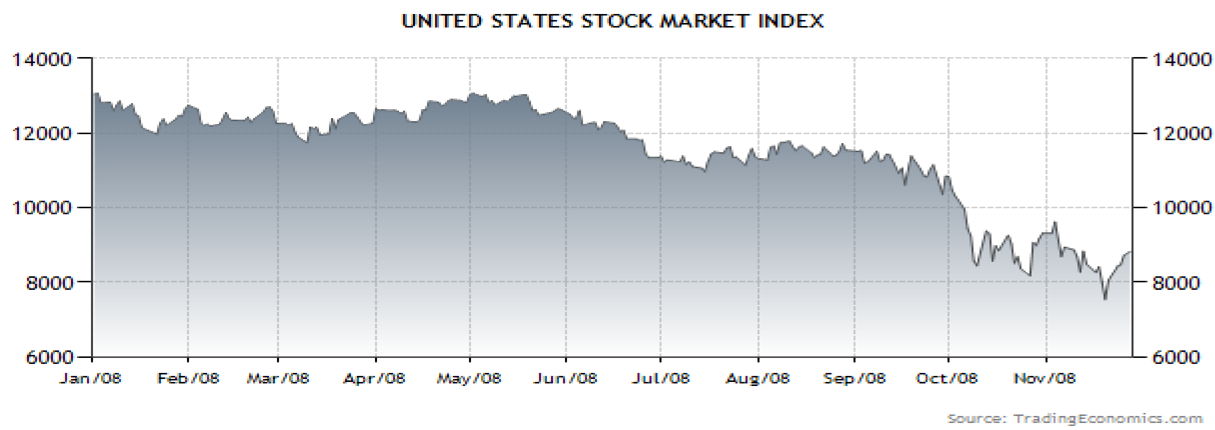
From 1987 until 2011 the CAC market value averaged 3264.13 points reaching an historical high of 6922.33 points in September of 2000 and a record low of 893.82 points in January of 1988. This page includes: France Stock Market Index chart, historical data and news.





From 1971 until 2011 the Dow Jones Industrial Average market value averaged 4739.10 points reaching an historical high of 14164.53 points in October of 2007 and a record low of 577.60 points in December of 1974. This page includes: United States Stock Market Index chart, historical data and news

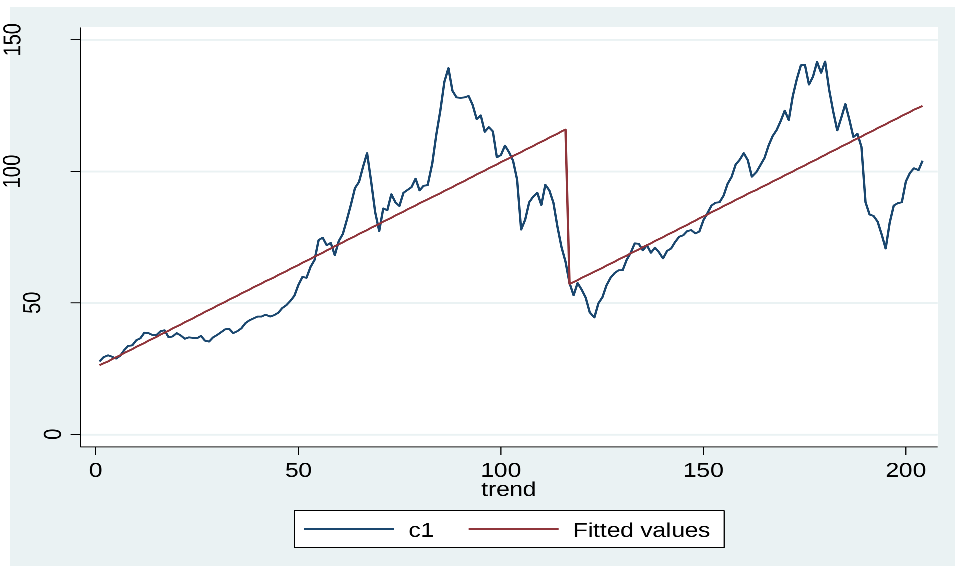



## Appendix II

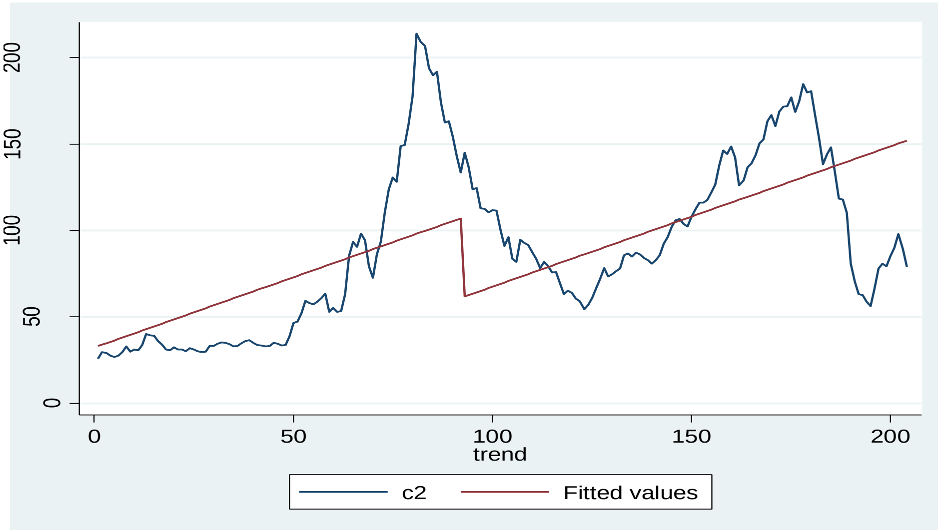
Below we provide (using **STATA 10**) the Line – graphs for the 5 time series, on which we overlay a fitted (using OLS) structural break model for the structural breaks given by our programs and fitting either model (A) or (C) depending on what seems to fit the data better following Perron's analysis for the prior examination of the series.

## DAX (Model A)



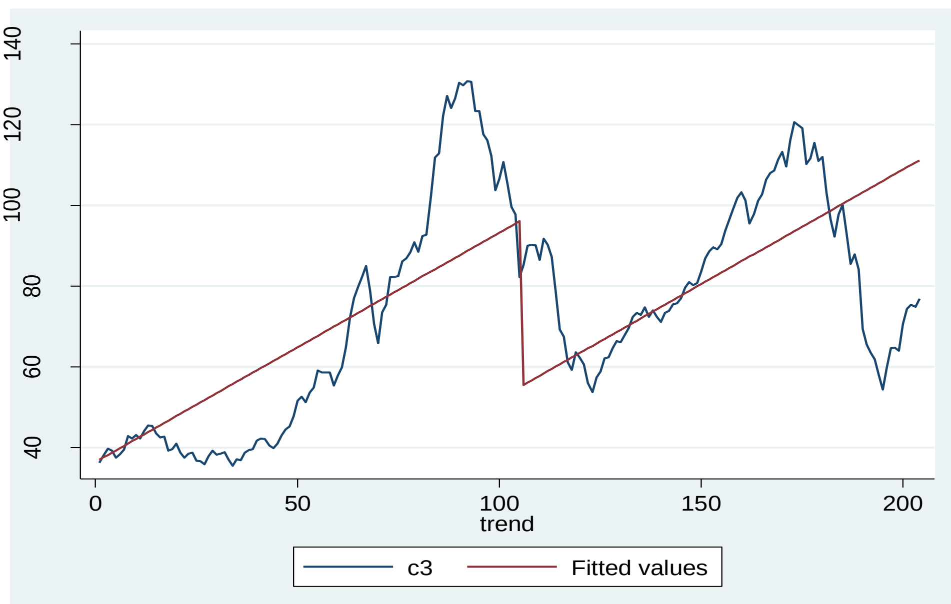

**Plot A1**: Time line plot for the DAI index. Fitted OLS trend of the form $\tilde{y}_t = \tilde{\mu} + \tilde{\gamma} DU_t + \tilde{\beta} t$ where $DU_t = 0 \text{ if } t \leq 116 \text{ and } \mathrm{DU}_t = 1 \text{ if } t \geq 116$

## ASEI (Model A)



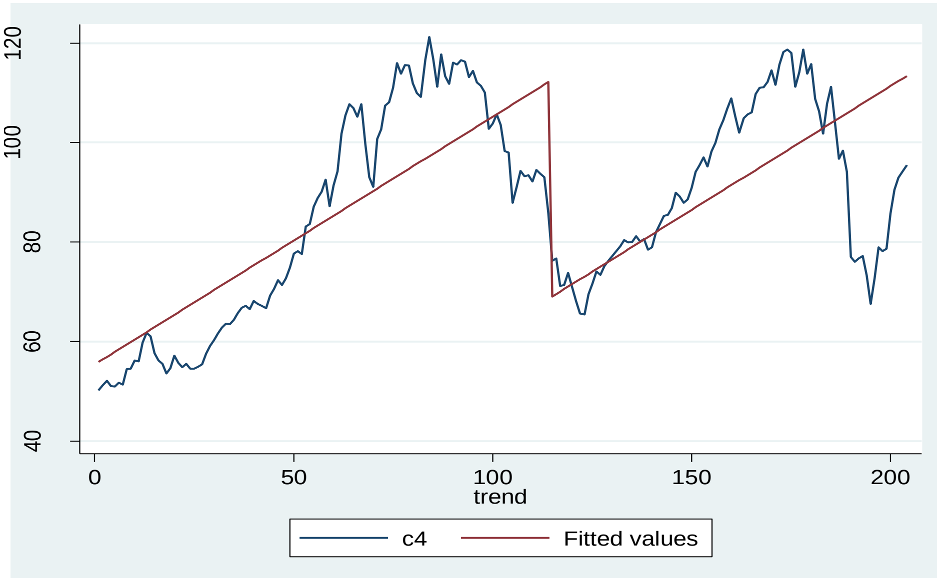

**Plot A2**: Time line plot for the ASEI index. Fitted OLS trend of the form $\tilde{y}_t = \tilde{\mu} + \tilde{\gamma} DU_t + \tilde{\beta} t$ where $DU_t = 0$ if $t \leq 92$ and $DU_t = 1$ if $t \geq 92$

## CAC40 (Model A)



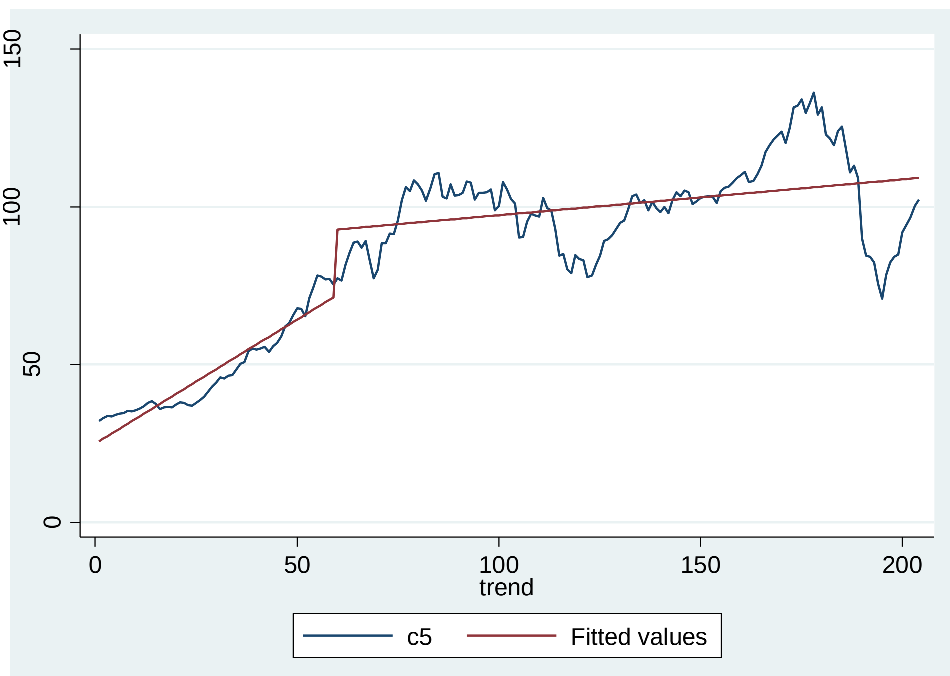

**Plot A3**: Time line plot for the CAC40 index. Fitted OLS trend of the form $\tilde{y}_t = \tilde{\mu} + \tilde{\gamma} DU_t + \tilde{\beta} t$ where $DU_t = 0$ if $t \leq 105$ and $DU_t = 1$ if $t \geq 105$

## FTSE 100 (Model A)




**Plot A4**: Time line plot for the FTSE100 index. Fitted OLS trend of the form $\tilde{y}_t = \tilde{\mu} + \tilde{\gamma} DU_t + \tilde{\beta} t$ where $DU_t = 0$ if $t \leq 114$ and $DU_t = 1$ if $t \geq 114$

## DOW (Model C)




**Plot A5**: Time line plot for the DOW index. Fitted OLS trend of the form $\tilde{y}_t = \tilde{\mu} + \tilde{\gamma}_1 DU_t + \tilde{\beta} t + \gamma_2 DT_t$ where $DU_t = DT_t = 0$ if $t \leq 59$ and $DU_t = 1$, $DT_t$=t if $t > 59$