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International Stock Markets: A Co-integration Analysis*

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Abstract:

This study investigates the degree of co-integration between five major European stock markets and five major non European stock markets. The results show that all five major European stock markets are co-integrated either positively or negatively, while among the five major non European the Canadian, the Japanese and the Singapore are non co-integrated with the others.

The results point towards a decreasing number of common stochastic trends influencing the stock markets, i.e. the degree of co-integration between the European stock markets has been increased during the recent decade.

Key Words: *Co-integration Analysis, Stock Markets, Stochastic Trends*

JEL Classification*: G10, G15*

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1. Introduction

A general implication of a simultaneous movement for the international stock markets has been raised from the fact that they seem to follow the same trend in the long as well as in the short run period. This relation cannot be interpreted by a linear equation, because financial time series are suffering from stochastic trends and drifts, making them non-stationary due to unit root problem.

The problem of a non-stationary series and the lack of identifying a dynamic model trustful to explain the reasons of equilibrium between the samples, due to the usual phenomenon of unit roots, has been exposed by Granger and Newbold (1974) and by Nelson and Plosser (1982) who manifested the possibility of predicting a model which will be spurious, or non sense. Box and Jenkins (1970) proposed another procedure to eradicate this instability by transforming the time series in differences and producing stationary ones. However, a problem of misspecification could be still implied because a level of integrated values produced by this method is not easily explainable.

This problem has been overwhelmed, as it is shown by Granger (1981) especially for the same level of a differentiated series, with a set of linear combinations which are stationary. In addition, Engle and Granger (1987) have established the procedure showing that series at the same level of integration can have equilibrium relations which are stationary while series at different levels of integration not. This relation is being denoted by the term of co-integration and reveals the simultaneous movement of a group of series which have a type of a long-term equilibrium. Johansen (1995) methodology examines this assumption with the maximum likelihood procedure which is preferable than the Engle and Granger methodology mainly because of the multivariate aspect of the former compare to the later. The Johansen's procedure is going to be use in this study in an attempt to evaluate the degree of co integration between five European and five non European stock markets.

2. Co-integration and Related Tests

Recently, a vast literature has appeared (see, e.g., *Eun and Shim, 1989; Koch and Koch, 1991; Brocato, 1994; Leachman and Francis, 1995; Francis and Leachman, 1998;* and *Bessler and Yang, 2003*) exploring the long-term co-integration relations and/or short term dynamic interactions among major international stock markets, which also involve some major European stock markets.

Two stock market indexes are said to be co-integrated if, in the long run, they do not drift "too far" apart. In a more formal definition, two variables are co-integrated "if the variables are integrated but a linear combination of these variables is stationary".

According to the co-integration theory, (see, e.g., *Arshanapalli and Doukas, 1993* for more details on the subject), if two stock markets are collectively efficient in the long run, then their stock prices cannot be co-integrated. There is more than one method of conducting co-integration tests, presented in the literature. Namely, two tests are nowadays being widely applied for testing the presence of co-integration.

The unit root tests of *Dickey and Fuller (1979; 1981)* are usually utilized to establish the order of integration. *Dickey and Fuller (1979, 1981)* provide one of the most influential works in the field of unit root tests. The Dickey- Fuller test can be applied both in the case of a lower AR process and a higher AR process.

Secondly, the co-integration of the variables is examined using the *Johansen (1988)* procedure. One can test the cross-country market efficiency hypothesis by means of the multivariate co-integration test of *Johansen (1991; 1988).* The Johansen co-integration test is applied to check for common stochastic trends, long-run relationships, between the stock indexes. The null hypothesis is that there is no co-integration among the stock prices. This procedure provides more robust results than other co-integration methods when there are more than two variables *(Gonzalo, 1994).*

Several authors have utilized unit-root and co-integration methodology in order to investigate for interdependence between major international stock markets. For example, *Chan, Gup and Pan (1992)* empirically examine the weak-form efficient market hypothesis for a series of 18 international stock markets by using unit root tests proposed by *Phillips, (1987)* and *Perron, (1988).* They also test whether these stock markets are collectively efficient by co-integration tests. Also, they investigate stock market integration by dividing the data into 4 sub-samples. The authors concluded that only few stock markets are co-integrated to other stock markets. Granger (1986) and M*cDonald* and *Taylor (1988; 1989)* have shown that the prices from two efficient markets cannot be co-integrated.

There is also a growing literature with a focus on stock markets within Europe. *Taylor and Tonks (1989)* and *Corhay, Rad and Urbain (1993)* found much evidence for co-integration among several major European stock markets in the late 1970s and 1980s. *Dickinson (2000)* argued that a co-integrating relationship among the major European stock markets exists after the 1987 stock crash and it may be partly driven by the long-run relationships of macroeconomic fundamentals among these countries. *Dickinson (2000)* also observed that short-run international linkages among major European markets, which do not appear in their long-run relationship increased greatly during that period. *Lin et al., (1989)* provide an excellent analysis of the reasons behind linkage of financial markets.

By contrast, *Chan, Gup and Pan (1997)* found little evidence for co-integration among several major European stock markets and among most European Economic Community member countries, particularly during the period after the 1987 crash. *Gerrits and Yuce (1999)* documented that the long-run relationship among major European markets has weakened during the period 1990–1994.

Pynnonen and Knif (1998) and *Knif and Pynnonen (1999)* extended consideration to small European well developed markets. *Pynnonen and Knif (1998)* reported little interaction between two Scandinavian stock markets, while *Knif and Pynnonen (1999)* found some positive evidence on the interdependence among small European markets.

Yang Min and Li (2003), using once again co-integration theory, examined the impact of the EMU on the long-run structure of European stock market integration by comparing co-integration relations among the eleven European stock markets and the US in two different periods, before and after the EMU. The authors utilize the co-integration trace test statistics *(Johansen, 1991)* to test the number of co-integrating vectors. The authors notice that two co-integrating vectors are found in both the periods before and after the EMU. The results clearly indicate that large EMU markets (Germany, France, Italy and the Netherlands) are more integrated with each other after the EMU. Several small EMU markets are also more integrated with the large EMU markets, while the three smallest EMU markets (Austria, Belgium and Ireland) became more isolated from other EMU markets after the EMU launched.

Another interesting work on the specific area was done by *Choudhry (1996),* who investigates the long-run relationship between international stock prices in the 1920s and the 1930s using unit root and co-integration tests, using stock indexes from six European countries (namely, France, Italy, Spain, Poland, Sweden and Czechoslovakia). Tests are conducted using, first, the longest time period and also using various sub-periods. Sample statistics (i.e. mean, variance, skew ness, and kurtosis) are also presented for each of the stock indexes. He reported that the results gave no evidence of co-integration between the specific stock markets.

3. Stationarity

Stock market time series used in this study must be examined for the level of their integration by using the Augmented Dickey-Fuller (1979, 1981) and Phillips and Peron (1988) methodologies. The value of the estimates of these tests in their first differences must be smaller than the critical values, indicating that the corresponding time series are integrated in first level I (1). When all stock market time series are integrated in first level I (1), the co-integration test proposed by Johansen can be conducted.

Consider a general kth order VAR model:

$$\Delta Y_t = D + \Pi Y_t - 1 + \sum_{i=1}^{k-1} \Gamma_t \Delta Y_t - 1 + \varepsilon_t$$

where Yt is an (n x 1) vector to be tested for co-integration and ΔYt = Yt- Yt-1. D is the deterministic term which may take different forms such as a vector of zeros or non-zeros constants depending on several properties of the data. Π and Γ are non unit matrices of coefficients. The co-integration relationship can be determined from matrix Π. If matrix Π = 0 there is no co-integration. In a bi-variable case, i.e. n = 2, the two variables are co-integrated only if the rank of matrix Π equals 1 (Johansen and Juselius 1990), considering that the kth order of VAR has a vector of εt, that is a multivariate normal white noise process with mean 0 and finite covariance matrix.

Johansen (1998) proposed to test for co-integration by examining a combination of null hypotheses as follows. If the rank of matrix Π = 0 there is no-co-integration in the set of series in question, if the rank of matrix Π = m, where m is the number of the series used, all the series m are stationary, and if the rank of matrix Π = r, where 0<r<1, then the series are co-integrated.

Alternatively co-integration can be tested by examining the trace and the maximum Eigenvalues as stated below:

$$\lambda_{trace} = -T \sum_{i=r+1}^{n} \ln(1 - \lambda_t)$$
$$\lambda_{\max} = -T \ln(1 - \lambda_{r+1})$$

where λ 1,…,λ r, are the r largest squared canonical correlations between the residuals obtained by regressing ΔYt and Yt-1 on ΔYt-1, …, ΔYt-k-1, where k = 0, 1, 2,...,n. The critical values are provided by MacKinnon, Haug and Michelis (1999) for p-values and by Osterwald and Lenum (1992) for λ (r).
In this case the hypotheses examined are:
Ho: r = 0 and Ha: r = 1, if λ (r) > critical value
Ho: r $\leq$ 1 and Ha: r = 2, if λ (r) > critical value
Ho: r $\leq$ m-1 and Ha: r = m, if λ (r) > critical value
The above test terminates where there is a non-significant result.

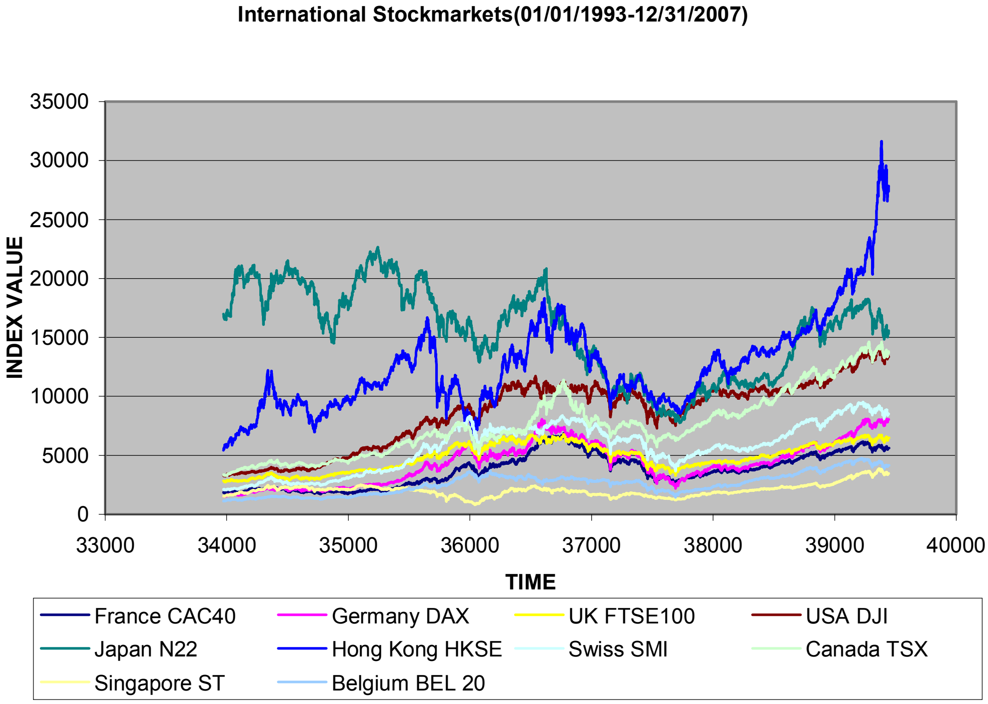
Inefficiency can be concluded if there is no sign of co-integration. However, if there is a co-integrated estimated equation, restrictions can be set for the static significance of the coefficients.

4. Data

Ten different stock market series are used in this study for the period 1993 to 2007 totalling 3145 observations each. Five of them are originated from Europe, namely CAC40, DAX, FTSE100, BEL, and SMI, two from North America, DJI and TSX, and three from Asia, NIKKEI, HKSE, and FTSE ST as it is shown in Figure 1. All series are considered to have a stochastic trend whereas in the co-integration equations are considered to have only an intercept. The logarithmic form of all the series, follow the first level of integration I (1). There is also no sign of autocorrelation in the residuals of all the differences used which can be verified by using the Lagrange Multiplier test.

The null hypothesis that is examined refers to the existence of a relation between the stock market series, co-integration, against the alternative of non existence of such a relation. Before the Johansen test has been applied, the rank of the appropriated VAR process must be determined. For calculations a smaller sample, consisting of data for a period of five years, is used and lag structure is being tested through the calculation of the corresponding Likelihood Ratio test statistic (Sims 1980). The test denotes that the maximum lag is a VAR (9) process. To determine the final co-integration model the order of the matrix Π which is $r < n = 10$ must be defined as well. The procedure shows that there is only one co-integration relation as it is shown in Table 2. The residuals of the co-integration equation are not correlated following the normal distribution. Finally, an error correction model (ECM) is also estimated.

Figure 1. Stock Market Indices 1993-2007



5. Empirical Evidence

The estimates of the coefficients of the final equation are considered as the long run relation coefficients of the stock market series. However, there are cases that the t-statistic is insignificant showing that the certain stock market index is not having great impact in the long-run trend of the dependant variable. Such cases are the TSX index, the NIKKEI index and the FTSE ST index. These stock market indices seem to have no significant statistic relation with all the other stock market indices even though for the long run equilibrium they are being affected by them. Generally speaking, the Asian stock market indices are following their own trends, while in the case of the HKSE index the high influence of western funds on it seems to be reflected clearly contributing in the long-run equilibrium.

The European stock market indices are having the same tendency except FTSE100 and SMI. Apparently, this is the effect of different economic strategies and the exclusion from the euro currency area. However, the most exogenous stock market index is the DAX, the short run parameter in the final equation is much higher compared to others, which can be contributed to the fact that German stock market is bigger in size and more saturated playing a crucial role in the European stock market as a whole.

The unit root test summary in the first part of Table 1 indicates that the series are suffering from unit root problem since the null hypothesis of non-stationarity is not rejected at 5% significance level. The problem disappeared in the second part of Table 1 where the first difference form of the series is used and the null hypothesis of non-stationarity is rejected at 5% significance level. All the series are examined individually and with an exogenous individual trend in each series.

Table 1. Unit Root Tests Summary, Stock Market Indices 1993-2007

Unit Root Test Summary		
Endogenous Variable: Log(x), where x = DJI, FTSE, e.t.c.		
Exogenous Variable: Individual Trend		
Automatic Selection of lags based on AIC: 0 to 28		
Ho: Non-stationarity		
Method	Statistic	Prob*
Ho: Unit Root		
ADF - Fisher Chi-squared	7,58	0,99**
PP - Fisher Chi-squared	6,78	0,99**
***Probabilities for Fisher tests are computed using an asymptotic Chi squared**		
Distribution. All other tests assume asymptotic normality.		
****Ho: Not rejected for a=0,05**		
Unit Root Test Summary(First Differences)		
Endogenous Variable: d(Log(x)), where x = DJI, FTSE, e.t.c.***		
Exogenous Variable: Individual Trend		
Automatic Selection of lags based on AIC: 0 to 28		
Ho: Non-stationarity		
Method	Statistic	Prob**
Ho: Unit Root		
ADF - Fisher Chi-squared	1.853,83	0***
PP - Fisher Chi-squared	2557,39	0***
***Probabilities for Fisher tests are computed using an asymptotic Chi squared**		
Distribution. All other tests assume asymptotic normality.		
****Ho: Rejected for a=0,05**		

As it is shown in Table 2 setting two different sets of hypotheses, the null hypothesis of Ho: r = 0 vs Ha: r = 1 in the first set is rejected while the null hypothesis of Ho: r = 1 vs Ha: r = 2 in the second set is not rejected based on the trace and max-Eigen statistics. Trace and max-Eigen estimates are less than their corresponding critical values at 5% significance level. This is an indication of one long run equilibrium equation in the sample examined.

Table 2. Johansson's Co-integration Equations, Stock Market Indices 1993-2007

	a=0,05					
	TRACE	C.V.	P-values	MAX-EIGEN	C.V.	P-values
Ho: r = 0 vs Ha: r = 1	244,4501*	239,2354	0,0285	76,36317*	64,50472	0,026
Ho: r = 1 vs Ha: r = 2	168,0869**	197,3709	0,5292	51,96976**	58,43354	0,1881
*Ho is rejected for a=0,0, **Ho is not rejected for a=0,05						

Table 3: Co-integration Equations b-Coefficients, Dependent Variables=Log(x), where x = HSKE, DJI, e.t.c, Stock Market Indices 1993-2007

LAG(9), a=0,05

	B coef	HKSE	TSX	BEL20	CAC40	DAX	DJI	FTSE100	NIKKEI	SMI	ST
1	HKSE	1	0,52	1,96	4,81	2,86	-3,75	-11,50	0,68	-1,75	-0,75
	t-statistic		0,76	4,23	3,69	3,64	-4,80	-6,96	1,36	-1,97	-1,33
2	TSX	1,92	1	*3,77*	9,26	5,51	-7,22	-22,13	1,31	-3,37	-1,44
	t-statistic	2,56		3,91	3,69	4,20	-4,90	-7,18	1,49	-1,97	-1,34
3	BEL20	0,51	0,27	1	*2,45*	1,46	-1,91	-5,87	0,35	-0,89	-0,38
	t-statistic	2,77	0,76		3,69	3,58	-4,82	-7,20	1,36	-1,98	-1,36
4	CAC40	0,21	0,11	0,41	1	*0,59*	-0,78	-2,39	0,14	-0,36	-0,16
	t-statistic	2,45	0,73	3,74		3,91	-4,93	-9,28	1,36	-1,98	-1,28
5	DAX	0,35	0,18	0,69	1,68	1	*-1,31*	-4,02	0,24	-0,61	-0,26
	t-statistic	2,49	0,86	3,74	4,04		-5,02	-7,01	1,35	-2,06	-1,30
6	DJI	-0,27	-0,14	-0,52	-1,28	-0,76	1	*3,06*	-0,18	0,47	0,20
	t-statistic	-2,46	-0,75	-3,78	-3,81	-3,76		7,16	-1,35	2,01	1,25
7	FTSE100	-0,09	-0,05	-0,17	-0,42	-0,25	0,33	1	*-0,06*	0,15	0,06
	t-statistic	-2,46	-0,76	-3,90	-4,95	-3,63	4,94		-1,37	1,98	1,22
8	NIKKEI	1,47	0,76	2,88	7,07	4,21	-5,52	-16,90	1	*-2,58*	-1,10
	t-statistic	2,47	0,80	3,76	3,71	3,58	-4,77	-7,02		-2,44	-1,21
9	SMI	-0,57	-0,30	-1,12	-2,74	-1,63	2,14	6,56	*-0,39*	1	0,43
	t-statistic	-2,45	-0,73	-3,76	-3,71	-3,74	4,88	6,94	-1,67		1,21
10	ST	-1,34	-0,70	-2,62	-6,44	-3,83	5,02	15,39	-0,91	2,35	1,00
	t-statistic	-2,69	-0,81	-4,20	-3,90	-3,85	4,92	6,98	-1,35	1,97	

Table 3 presents the b coefficients and t-statistics estimated for each particular equation when alternative dependant variable is set in each case in a form of Log(x), where x = DJI, FTSE, e.t.c. The estimated variables are in vector form transformed in a linear equation for every single equation.

As it is shown in Table 3 the b coefficient of the Canadian stock market index (TSX) is not significant at 5% level in any single equation, since all corresponding t-statistics are less than the critical value, indicating no significant effect of this index to the other stock market indices, however it is affected by all other indices except the Japanese (NIKKEI) and the Singapore (ST) stock market index.

The Japanese stock market index (NIKKEI) is not significant at 5% level in any single equation, since all corresponding t-statistics are less than the critical value, indicating no significant effect of this index to the other stock market indices; however it is affected by all other stock market indices except the Canadian (TSX) and the Singapore (ST) stock market index.

The Singapore stock market index (ST) is not significant at 5% level in any single equation, since all corresponding t-statistics are less than the critical value, indicating no significant effect of this index to the other stock market indices; however it is affected by all other stock market indices except the Canadian (TSX) and the Japanese (NIKKEI) stock market index.

In all other cases there is a strong evidence of co-integration, positive or negative depending on the sign of the corresponding b coefficient, between the stock market indices of the study.

The co-integration graph, as it is shown in Appendix 1, reflects the influence between the stock market indices. From 1993 till the early 00's the co-integration equation follows a seemingly unrelated movement with high and low peaks in an irregular pattern. A significant change is being noted after the late 90's and early 00's when the markets started to have a more related course. This period was determined by highly bearish trend and then the stabilization, before the bullish rally of the period from 2003 till the first quarter of 2007 to be started. Profoundly, the bullish attitude of all the global investors and the high cash flow with the combination of the globalization efforts enhanced the economies and make them more vulnerable to global effects. This change on economies has been reflected in the stock market indices too, which seem to be more affected by one another.

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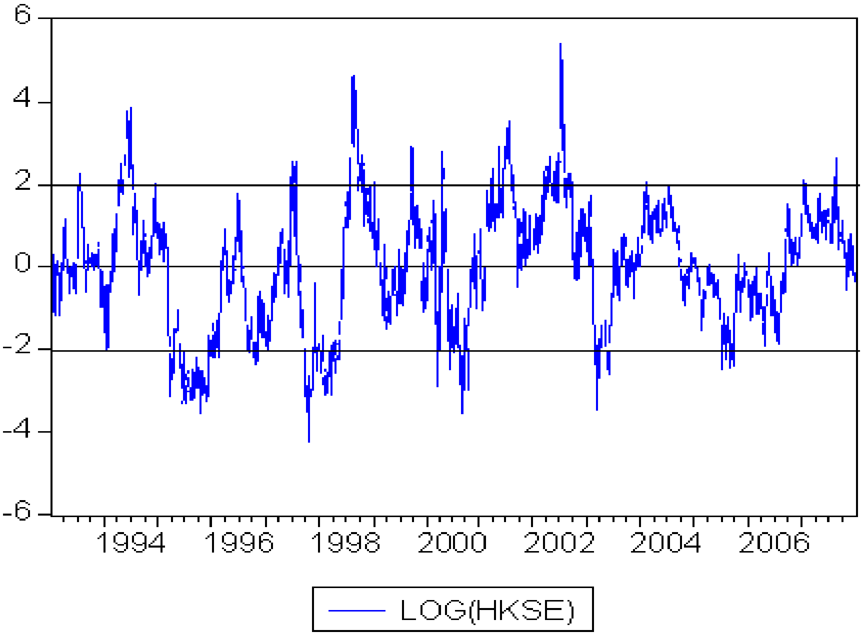
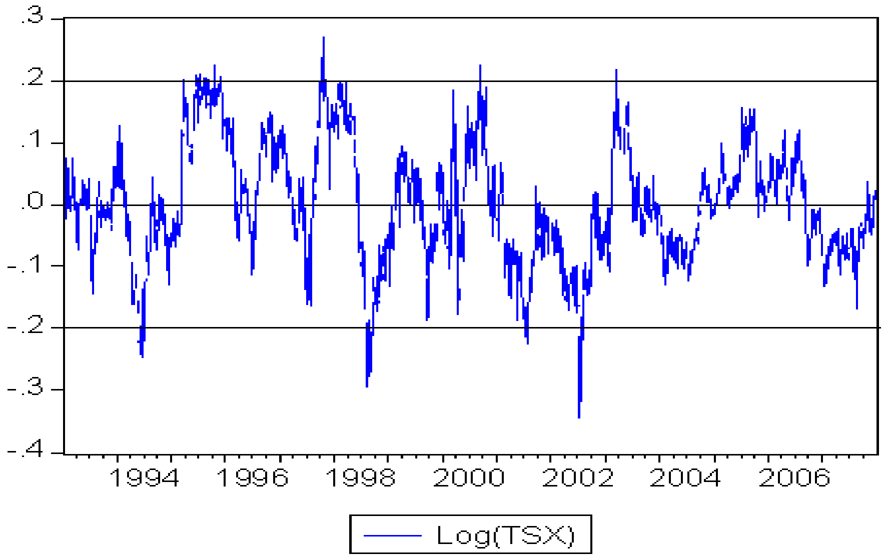
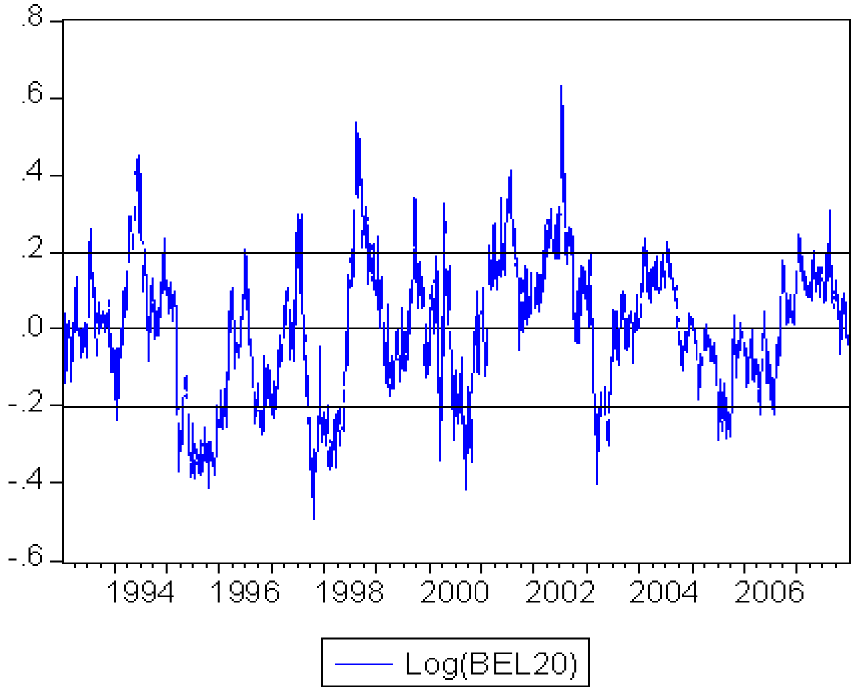
Appendix 1: Co-integration Equation, Stock Market Indices 1993-2007



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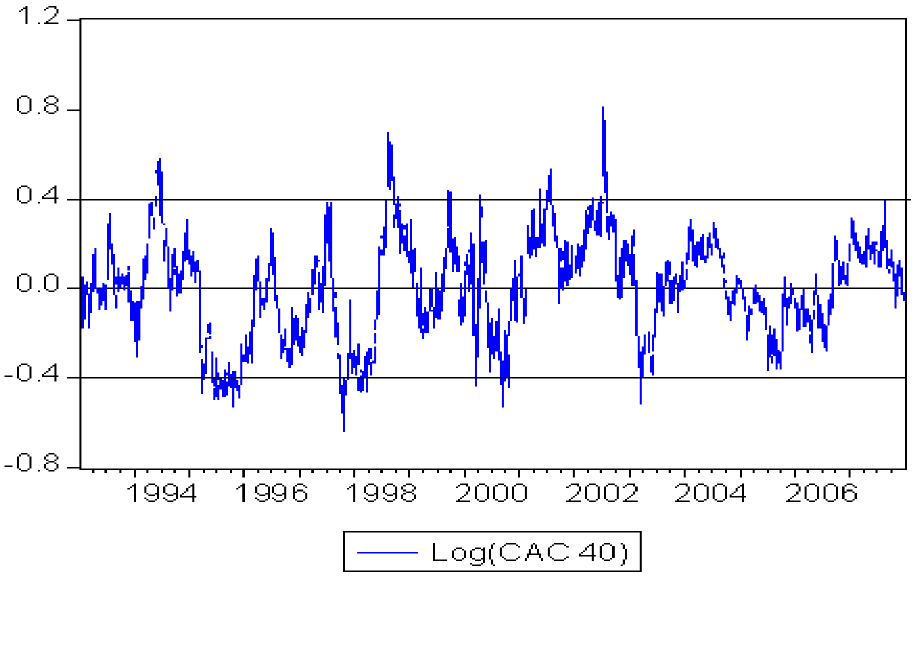
-.4
-.6
1994
1996
1998
2000
2002
2004
2006
Log(BEL20)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1996
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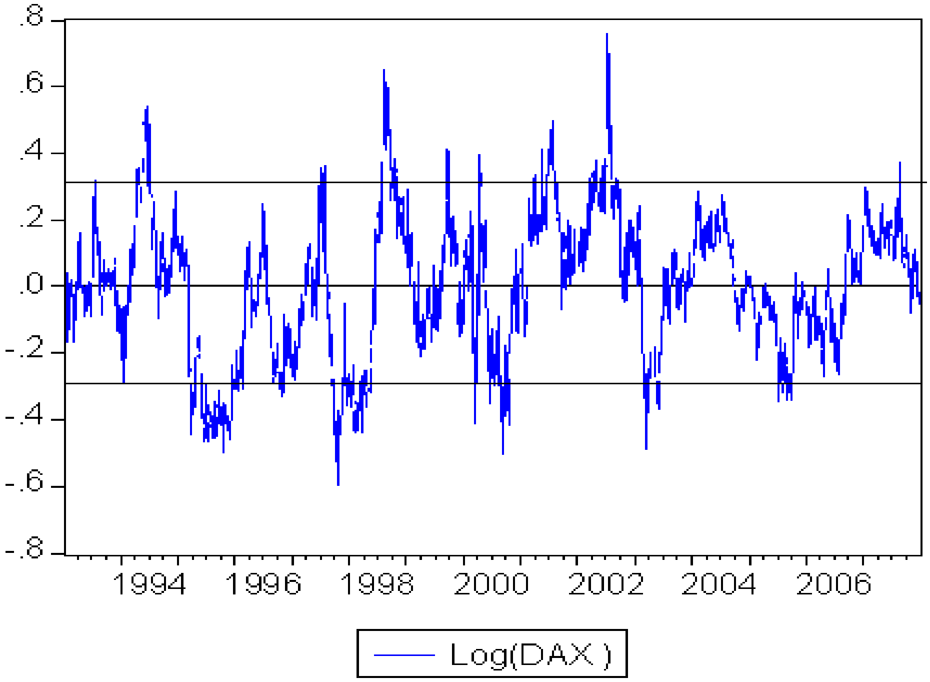
2004
2006
Log(CAC 40)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2006
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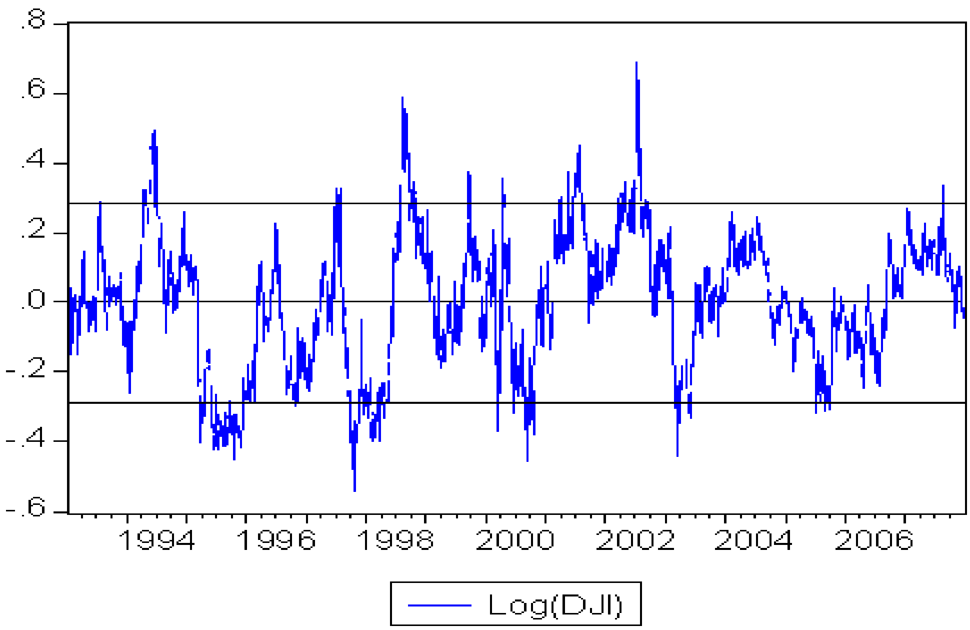
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1994
1996
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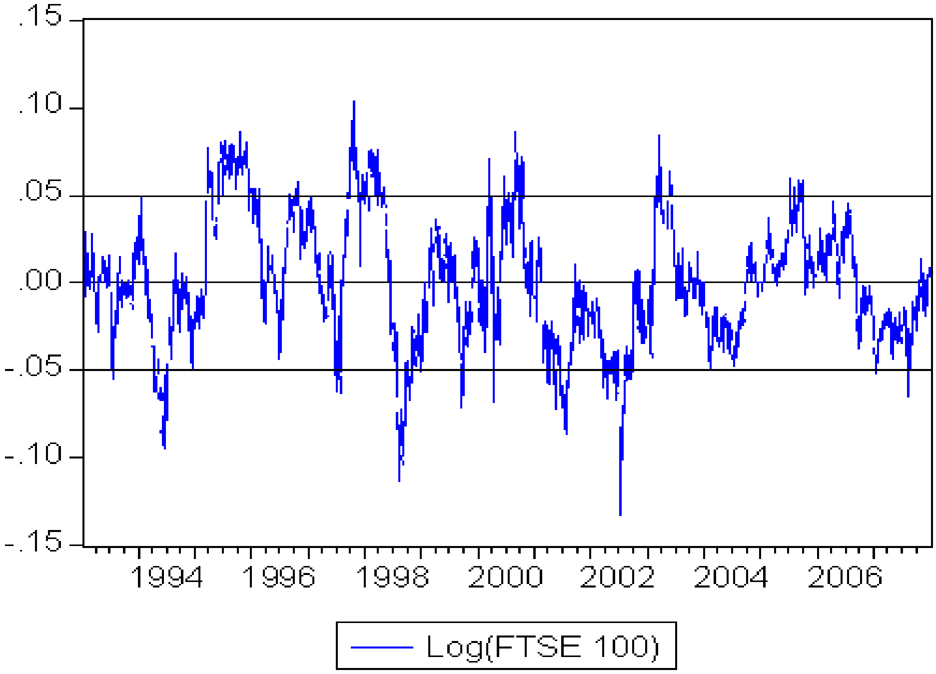
2004
2006
Log(DJI)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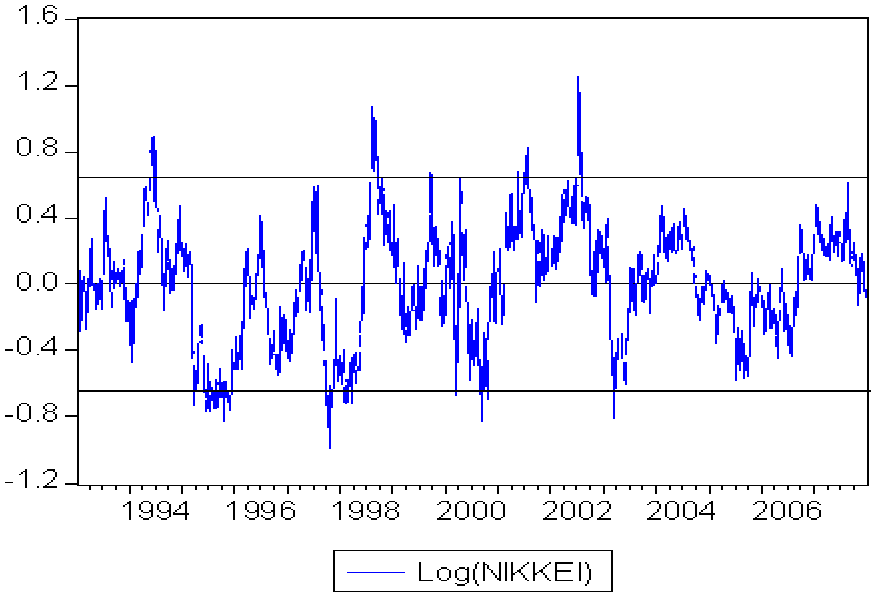
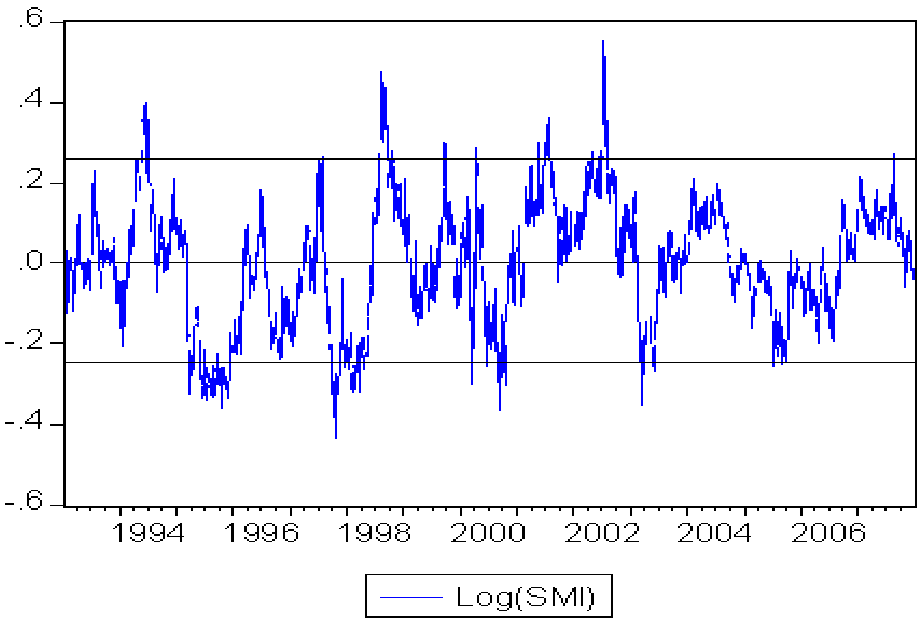
2004
2006
Log(FTSE 100)


1.6
1.2
0.8
0.4
0.0
-0.4
-0.8
-1.2
1994
1996
1998
2000
2002
2004
2006
Log(NIKKEI)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.4
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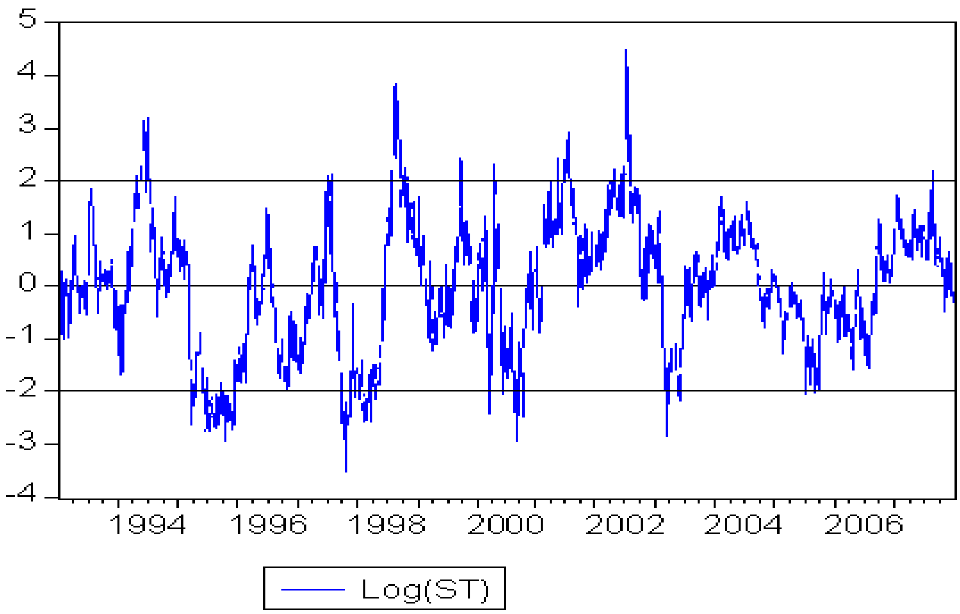
-.4
-.6
1994
1996
1998
2000
2002
2004
2006
Log(SMI)


5
4
3
2
1
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-1
-2
-3
-4
1994
1996
1998
2000
2002
2004
2006
Log(ST)