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Dynamic Linkages among the Equity Markets of the U.S and the European Countries: Recent Evidence based on Cointegration and Causality Tests

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This paper investigates the dynamic linkages among the equity markets of the US (proxied by S&P 500), Germany(proxied by DAX30 , France (proxied by CAC30), UK (proxied by FTSE100) and other 14 other major Eurozone markets (proxied by STOXX 600) using daily stock series from March 3, 2010 through April 17, 2018. Data are collected from the Bloomberg Database and the econometric models are estimated applying the most recent version of Econometric software (EViews 11). Jarque-Bera statistic shows non-normal distribution of the series. Augmented Dicky Fuller test indicates nonstationarity in level series and stationary in first differenced series. Applying Johansen Cointegration technique the study finds that stock price indices of these countries have long-run (equilibium) relationship. Applying the Granger-causality test, strong unidirectional causality has been detected from the US to 16 European markets except for the UK. No causality has been found from the European markets to the US market, indicating that the US market is the leader and the Euro markets are the followers. This is not surprising given the robust US economic growth during the period of our study A strong unidirectional Granger causality has been detected from Germany to the France market with 1 through 5 days lag. A weak unidirectional Granger causality is found from the UK to other Eurozone markets, and from the French to the UK market. In the case of Europe, Frankfurt stock market strongly affects the Paris bourse as well as other Eurozone markets. This result is also not surprising given the high economic growth rates of Germany and French during the sample period and the unfavorable impact of Britain exit from the European Union (BREXIT).

1. Introduction and Justification

Linkages among global stock markets have generated considerable interest in academia, portfolio managers, individual investors the pension fund maagers in order to reduce the risk and enhance the benefit. The robust performance of the US and some European economies over the last several years, portfolio managers and the individual investors have heavily invested in these markets. Statistics indicate that the flow of invested capital to these countries has experienced a phenomenal growth. Existing literature reveals the greater part of the research has been directed to a few developed equity markets with insufficient information. Asprem (1989), for example, compared the effects of economic factors on the stock markets of 10 European countries. While Bulmash & Trivoli (1991) did similar studies in the US market. Peiro (1996) compared such relationships in 3 European countries with the US. Cheng (1995) and Poon & Taylor (1991) examined the UK market. The number of similar studies using low frequency data from Eurozone countries is

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considerably outdated. This study thus aims to narrow the gap by examining a vast majority of Eurozone equity marketsin in addition to the US market. Inaddition to 3 major European markets (UK, France and Germany), 14 other Eurozone indices, listed in the **STOXX-600**, are included in our study. They are Austria, Belgium, Denmark, Finland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Spain, Sweden, and Switzerland. With a fixed number of 600 components, the Index represents large, mid and small capitalization companies across 17 countries of this European region, covering approximately 90% of the market capitalization. Many significant international events occurred during the period of this study such as Iran nuclear deal and subsequent US withdrawal with sanctions by Trump Administration, US Trade war with China, Britain exit from the European Union (BREXIT).

The objective of this paper is thus to provide new evidence on the question of interdependence among the US (S&P500). U.K (FTSE-100). France (CAC-40), Germany (DAX-30) and STOXX-600 Eurozone equity series. We investigate whether there are any cointegration among these markets as well as direction of causality between two markets. Cointegration implies that nonstationary times series move stochastically together toward some long-run stable relationship, the existence of cointegrating relationships among various indices has a direct implication in terms of the existence of common trends among these series. Cointegration also implies the existence of a Granger causality property between the series. This framework is attractive if the purpose is to study both comovements and dynamic relationships by portfolio managers and individual investors in order to enhance the diversification benefits.

The remainder of this paper is thus organized as follows. Section II briefly discusses the Indexes. Section III discusses the methodology and the data. The empirical results are discussed in Section IV while Section V concludes with some remarks.

2. Descriptions of the Indexes

The S&P500 (Standard & Poor's 500 Index) is US market index that measures the stock performance of 500 large, medium and small companies listed on stock exchanges and thus represents the overall market. It is the most commonly followed equity Index and is considered it to be the best representation of the US overall market. Although the index includes only companies listed in the US, it also includes many multi-national companies. The **FTSE-100 Index (**Financial Times Stock Exchange 100 Index), an Index of the 100 companies listed on the London Stock Exchange with the highest market capitalization. The index is maintained by the FTSE Group, a subsidiary of the London Stock Exchange Group. The Index broadly consists of the largest 100 qualifying UK companies by full market value. Many of these are internationally focused companies. Even though the FTSE All-Share Index is more comprehensive, the FTS-100 is by far the most widely used UK stock market indicator.

The **DAX-30** (Deutscher Aktien index) is German blue chip stock market index consisting of the 30 major German companies trading on the Frankfurt Stock Exchange. Prices are taken from the Xetra trading venue. It is the equivalent to US Dow Jones Industrial

Average.

The CAC- 40 is a benchmark French stock market index. The index represents a capitalization-weighted measure of the 40 most significant values among the 100 highest market caps on the Euronext Paris.

The **STOXX Europe 600** (**STOXX-600**) is an Index of European stocks designed by STOXX Ltd. The Index is derived from the STOXX Europe Total Market Index, and is a subset of the STOXX Global 1800 Index. With a fixed number of 600 components, the Index represents large, mid and small capitalization companies across 17 countries of the European region, covering approximately 90% of the free-float market capitalization of the European stock market: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

3. Methodology and Hypotheses

Unit Root Test (Stationary)

Augmented Dickey Fuller (ADF) test is used to determine whether time series represented by daily equity prices is nonstationary (has unit root). ADF requires running a regression of the first difference of the series against the series lagged once, lagged difference terms, a constant and a time trend such as

$$\Delta \mathbf{x}_t = \lambda_0 + \lambda_1 X_{t-1} + \lambda_2 T + \Sigma \lambda_i \Delta \mathbf{x}_{t-I} + \epsilon_t \qquad i = 1 \ldots\ldots\ldots\ldots k \qquad (1)$$

where Δ is the first difference operator, ϵ_t is an error term, k is the number of lagged first difference term and is determined such that ϵ_t approaches to white noise. The null hypothesis specifies nonstationary series or unit root (H_o: $\lambda_1 = 0$) . Output of the ADF test consist of the t-statistic on the estimated coefficient of the lagged variable (λ_1) and the Mackinnon critical values for the test of a zero coefficient. If the estimated coefficient is significantly different from zero then the H_o is rejected, suggesting the series are stationary.

Cointegration Test

The theory of cointegration, first introduced first by Granger (1981) and then developed by Granger (1986) and Engle and Granger (1987), integrates the short-run dynamics with long-run equilibrium relationship. A set of time-series variables are said to be cointegrated if they are integrated of the same order and a linear combination of them is stationary. Such linear combination would then point to the existence of a long-term relationship among the variables. Since our interest is searching for long run linkages in the stock prices, we consider the five series to investigate the presence of potential common trends among them. This study first investigates on the first order nonstationary integrated process i.e. I(1). The implications of cointegration are numerous, both from economic and statistical points of view. In particular if there are **r** stable long-run relationships (cointegrating equations) in **k** dimensional vector of time series, then these **k** series share

k-**r** common stochastic trends. On the other hand, given the unique relationship between cointegration and the error correction models, then there must be some Granger causality (i.e., precedence) in at least one direction. This paper exploits these relationships and investigates the presence of common stochastic trends by means of the vector autoregressive representation. We derived a maximum likelihood approach for estimating and testing the number of cointegrating relationships among the components of a k-vector x_i of variables. Assuming a simple vector autoregressive (VAR) model for x_i:

$$\boldsymbol{A(L)}\, x_i = \epsilon_t \qquad (2)$$

which can be reparametrized in a vector autoregressive ECM:

$$\Delta x_t = \Sigma_i \prod_i \Delta \mathbf{x}_{t-I} + \prod p \mathbf{x}_{t-p} + \epsilon_t \qquad (3)$$

where I = 1,2, ……..p-1.

$\Pi_i = -1+A_1 + A_2 + \ldots\ldots.. + A_i$ with I=1,…….,p.

If rank (Π_p) = r<k, there are r-k unit roots in the system and r linear combinations which are stationary, that is, there are r cointegrating relationships. Π_p can be written as $\alpha\beta'$ where both α and β are (k x r) matrices of full column rank. The first r rows of β' are the r cointegrating vectors in the different equations. The maximum likelihood estimate of the cointegrating vector is given by the empirical canonical variates of X_{t-p} with respect to Δx_t corrected for the short- run dynamic and the deterministic components. The number of cointegrating relationships is given by the number of significant canonical correlations. Their significance can be tested by means of a sequence of likelihood ratio tests. Once the number of cointegrating relationships has been determined, it is possible to test particular hypothesis concerning α and β using standard χ^2 (chi-square) distributed likelihood ratio test. We consider the above six stock price indices jointly in a model such as equation (4). The specification of the lag length of the model is tested sequentially using likelihood ratio test statistics.

The Granger Test for Causality

The Granger approach to the question of whether X and Y are Granger causality related is thus to see how much of the current *Y* can be explained by past values of *Y* and then to see whether adding lagged values of X can improve the explanation. Y is said to be Granger-caused by X if X helps in the prediction of Y, or equivalently if the coefficients on the lagged values of X are statistically significant.

More specifically let us consider the following two variable VAR model:

$$Y_t = \alpha_{10} + \sum \alpha_{1i} X_{t-i} + \sum \beta_{1j} Y_{t-j} + \varepsilon_{1t} \qquad (4)$$

$$X_t = \alpha_{20} + \sum \alpha_{2i} X_{t-i} + \sum \beta_{2j} Y_{t-j} + \varepsilon_{2t} \qquad (5)$$

where ε_t is white noise, p is the order of the lag for X, and q is the order of the lag for Y. With respect to this model we can distinguish the following cases:

(i) If $[\alpha_{11}, \alpha_{12}, \ldots, \alpha_{1p}] \neq 0$ and $[\beta_{12}, \beta_{13}, \ldots, \beta_{1q}] = 0$, there exists a unidirectional causality from X_t to Y_t, denoted as X → Y.
(ii) If $[\alpha_{21}, \alpha_{22}, \ldots, \alpha_{2p}] = 0$ and $[\beta_{21}, \beta_{22}, \ldots, \beta_{2q}] \neq 0$, there exists a unidirectional causality from Y_t, to X_t, denoted as Y → X.
(iii) If $[\alpha_{11}, \alpha_{12}, \ldots, \alpha_{1p}] \neq 0$ and $[\beta_{21}, \beta_{22}, \ldots, \beta_{2q}] \neq 0$, there exists a bidirectional causality between X_t to Y_t, denoted as X ↔ Y.

Thus the hypotheses are as follows

H_0: X does not Granger-cause Y, i.e. $[\alpha_{11}, \alpha_{12}, \ldots, \alpha_{1p}] = 0$, if F-statistic < critical value of F.
H_1: X does Granger-cause Y, i.e. $[\alpha_{11}, \alpha_{12}, \ldots, \alpha_{1p}] \neq 0$, if F-statistic > critical value of F.

and

H_0: Y does not Granger-cause X, i.e. , $[\beta_{21}, \beta_{22}, \ldots, \beta_{2q}] = 0$ if F-statistic < critical value of F.
H_1: Y does Granger-cause X, i.e. $[\beta_{21}, \beta_{22}, \ldots, \beta_{2q}] \neq 0$, if F-statistic > critical value of F.

The Data and the Sample

As described earlier, the data set comprises daily market indexes of S&P500, DAX-30, FTSE-100, CAC-40 and STOXX-600. The series span the period from March 10, 2010 to April 17, 2018. The sample for each country contains all days of the week except weekends. The source of the data is Bloomberg that publishes stock market data for all countries. Theses Indices are selected to represent the market index of each country reflecting the overall performance of their economies. The **S&P500** is a value weighted index representing approximately 75% of the total market capitalization of the US stock market. The **FTSE-100** is the principal index in the UK and consists of the largest 100 companies by full market value. The **DAX-30** is a price-weighted index of the 30 most heavily traded stocks in German market, while **CAC-40** is calculated on the basis of 40 best France companies listed in Paris bourse. The **STOXX 600** Index represents large, mid and small companies across 17 European countries.

4. Empirical Results

In order to estimate the models, this study applied the recent version of the Econometric software (**Eviews 11)**. Empirical results reported here are comprised of descriptive statistics, stationarity tests, Johansen multivariate cointegration and the Granger causality tests. The first part of the analysis is based on descriptive Statistics in **Table 1**A, provides the summary statistics of all Markets. All indices in levels display “stylized’ facts common to most financial and macroeconomic data such as non-normality in the form of fat tails. As indicated by skewness statistics, Indices are either positively skewed (S&P500, FTSE-100, DAX-30) indicating right tail or negatively skewed (CAC-4, SOXX600) indicating left tail; supporting that these indices have asymmetric distributions. The kurtosis of all indices is lower than normal distribution (less than 3). The Jarque-Bera test combines both the skewness and the kurtosis, strengthens the conclusion that the null hypothesis of normality is rejected decisively for all series at the 5% level. The second part of the analysis is based on the correlation matrix in **Table 1B.** Correlation coefficient between the indices provides the degree of integration/relationship of the markets, and provides first hand useful information for the diversification benefit in terms of reducing portfolio risk. The US market is highly integrated with all European markets except for UK and the UK market is less integrated with other European markets. One plausible reason is the impact of BREXIT. Our findings also indicate the integrated Eurozone economies, consistent with increased economic and financial integration among them. This result is contrary to all previous studies using the information before BREXIT.

Table 1: Descriptive Statistics

	SP500	**STOXX600**	**FTSE00**	**DAX30**	**CAC40**
MEAN	1792.248	391.5578	9590.251	9035.728	5196.591
MEDIAN	1857.620	389.9107	9547.893	9252.940	5182.452
MAXIMUM	2872.870	498.2690	11783.51	13559.60	6877.709
MINIMUM	1022.580	285.1935	7093.828	5072.330	3653.862
Std. Dev	461.6288	46.29614	896.9781	2223.130	643.0373
SKEWNESS	0.177077	-0.105061	0.164203	0.174854	-0.044877
KURTOSIS	1.983579	2.215082	2.658248	1.856451	2.545507
Jarque-Bera	96.39993	54.93810	18.69235	118.9880	17.85811
Probability	0.000000	0.000000	0.000087	0.000000	0.000132
Sum	3579120.	781940.9	19151731	18044348	10377593
Sum Sq. Dev.	4.25E+08	4278091.	1.61E+09	9.86E+09	8.25E+08
No of Observations	**1997**	**1997**	**1997**	**1997**	**1997**

Correlation Matrix

SP500	STOXX600	FTSE100	DAX30	CAC40
1	0.70479000...	-0.1759634...	0.97048284...	0.60724491...
0.70479000...	1	0.23526121...	0.74017795...	0.91568884...
-0.1759634...	0.23526121...	1	-0.1256127...	0.17469465...
0.97048284...	0.74017795...	-0.1256127...	1	0.65705873...
0.60724491...	0.91568884...	0.17469465...	0.65705873...	1

Stationary (Unit root) Tests

As the study uses the time series data and aims at possible long-run equilibrium relationships among them, it is necessary to check whether the series are stationary in levels and in difference in order to avoid spurious results. Therefore the study applies the Augmented Dickey-Fuller (ADF) test for stationarity (unit root) to each index. **Table 2 p**rovides the summary results of the ADF test on level series and in their first differences. Each index is found to be non-stationary in level, but found to be stationary in first differenced series.

Table 2: Summary of ADF Unit Root Test

Country (INDEX)	**ADF Coeffic. in levels**	**Macki--non critical value**	**ADF Coeffi. in first difference**	**Macki--non critical value**
	τ_μ	τ_t	τ_μ	τ_t
U.S.A (S&P 500)	-1.274	-3.433	-46.75**	-3.433
Europe (Stoxx600)	-1.987	-3.433	-43.63**	-3.433
U.K (FTSE 100)	-2.398	-3.433	-31.71**	-3.433
Germany (DAX)	-2.511	-3.433	-44.29**	-3.433
France (CAC40)	-1.959	-3.433	-44.88**	-3.433

Note: **(*) indicate rejection of null hypothesis of unit root (non-stationary) at the 1% & (5%) level of significance, respectively. Mackinnon critical value for rejection of hypothesis of a unit root has been applied at the 1% & 5% level. Optimum lag structures are determined by the Akaike and Schwarz information criteria.

Cointegration Test

Engel and Granger (1987) suggest if two non-stationary variables converge to long-run equilibrium, then a stationary combination of these two variables should exists. Such variables are then called cointegrated; and the vector that transforms the no-stationary variables into stationary is called cointegration vector. Test for cointegration suggested by Engle and Granger was extended by Johansen to a multivariate case. Both tests rely on the assumption that stability of the cointegration vector is stable over time. We thus applied Johansen Cointegration techniques and the maximum likelihood estimator to determine the number of cointegrating equations (relationships) in equity markets. The purpose is to detect the long-run (equilibrium) as well as the short-run (dynamic) relationships among these markets. If the series are cointegrated, then a vector error correction (VEC) model will be estimated. Otherwise, an unrestricted vector autoregression (VAR) would be appropriate. The summary results of the Johansen's cointegration test are reported in

Table 3, Both the trace and the maximum eigenvalue tests support the hypothesis of at most one cointegrating equation, implying long-run equilibrium relationship among the US and the European markets.

Table 3: Summary of Johansen Cointegration Tests

Sample: Daily Series from March 2010 through April 2018
Sample size 1788 after adjustments (adjusted) 6 2042
Trend assumption: No deterministic trend
Series: S&P500 STOXX600 FTSE100 DAX CAC40
Lag intervals (in first differences): 1 to 4

Table 3A: Unrestricted Cointegration Rank Test (Trace) (λ_{trace})

Hypothesized		***Trace***	5 Percent	
No. of CE(s)	Eigenvalue	***Statistic***	Critical Value	Prob**
None *	0.031880	101.7577	60.06144	0.0000
At most 1*	0.014226	**43.82773**	40.17493	0.0205
At most 2	0.007921	18.21070	24.27596	0.2400
At most 3	0.002225	3.992459	12.3200	0.7120
At most 4	5.85E-06	0.010461	4.129906	0.9395

** denotes rejection of the hypothesis at the 5%level*
Trace test indicates 2 cointegrating equation(s) at the 0.05level
***Mackinnon-Huang-Michelis (1999) p-values*

Table 3B: Unrestricted Cointegration Rank Test (Maximum-) (λ*max*)

Hypothesized		***Max-Eigen***	5 Percent	
No. of CE(s)	Eigenvalue	***Statistic***	Critical Value	Prob**
None *	0.031880	57.92997	30.43961	0.0000
At most 1*	0.014225	**25.61703**	24.15921	0.0316
At most 2	0.007921	14.21824	17.79730	0.1595
At most 3	0.002225	3.981998	11.22480	0.6313
At most 4	5.85E-06	0.010461	4.129906	0.9335

**denotes rejection of the hypothesis at the 5% level.*
***Mackinnon-Huang-Michelis (1999) p-values*
Max-eigenvalue test indicates 2 cointegrating equation(s) at the 5% level.

Granger Causality Tests

Results of Granger Causality tests are reported in **Table 4**. We test the null hypothesis that one stock market does not Granger cause another y market both at the 1 percent and 5 percent significance levels with one to five days lag interval. Bidirectional Granger causality has been detected between the France (CAC-40) and the STOXX-600 Indices. A strong unidirectional causality is found only from the US (S&P500) market to all European markets except for the UK (FTSE-100). This is not surprising given the robust US economic growth since 2010. Also a strong unidirectional Granger causality has been detected from the German (DAX-30) to France (CAC40) with 1 to 5 days lag. A weak unidirectional Granger causality is found from the UK (FTSE-100) to STOXX-600 and from the CAC-40 to FTSE-100. The overall results implies that the US market leads the Eurozone markets, not vice versa. In the case of Euro markets, German market (DAX-30) strongly affects the French Bourse (CAC-40) and other Eurozone markets (STOXX-600). This result is also not surprising given the high growth rates of Germany followed by French, and the impact of the UK's withdrawal from the EU (BREXIT).

Table 4: Summary of Granger Causality Tests

Null Hypothesis	1% level of Significance	5% level of significance
S&P500 ≠ =>STOXX600	(1,2)	(3,4,5)
STOXX600 ≠ => S&P500	No	No
S&P500 ≠ =>DAX	(1,2,3,4,5)	----
DAX30 ≠ => S&P500	No	No
S&P500 ≠ =>FTSE100	No	No
FTSE100 ≠ => S&P500	No	No
S&P500 ≠ =>CAC40	(1,2,3)	(4,5)
CAC40 ≠ => S&P500	No	No
FTSE100 ≠ >STOXX600	No	(1)
STOXX600 ≠ =>FTSE100	No	No
DAX30 ≠ =>STOXX600	(1,2,3,4,5)	----
STOXX600 ≠ =>DAX30	No	No
CAC40≠ =>STOXX600	(1,2,3,4,5)	---
STOXX600≠ =>CAC40	No	(3,4,5)
FTSE100 ≠ >DAX	No	No
DAX30 ≠ >FTSE100	No	No
FTSE100 ≠ >CAC40	No	No
CAC40 ≠ >FTSE100	No	(3,4)
DAX30 ≠ >CAC40	(1,2,3,4,5)	-----
CAC40 ≠ >DAX	No	No

Note: "≠ =>" indicates does not "Granger Cause". Numbers in parenthesis indicate the lag length in days.

5. Conclusions

In this study we examine long-run equilibrium relationships and linkages of the US and the 17 major European equity markets using high frequency, daily series. These markets are relatively dominant in terms of market capitalization and trading volume. Data are collected from the Bloomberg database from March 10, 2010 through April 17, 2018. Empirical results comprise of Augmented Dickey Fuller tests of stationarity, Johansen multivariate tests of cointegration, and the Granger causality tests. The ADF test show that the level series are supportive to random walk hypothesis (unit root) for all indices. However, first differenced series are found to be stationary. Applying Johansen multivariate cointegration test, our results show that all indices are cointegrated as the null hypothesis of no cointegration is rejected at the 5 percent level of significance. This holds with different assumptions about linear and quadratic trends or no trend in the data. Finally we performed Granger causality tests at the 1 percent and 5 percent significance levels unto five days lag intervals. Test results indicate that there is a strong unidirectional causality from the US S&P500 to all European markets except for the UK FTSE-100 market. This is not surprising given the strongest economic growth of the US since 2010. Also a strong unidirectional Granger causality has been detected from the Garman DAX-30 to the France CAC-40 with 1 through 5 days lag. A weak unidirectional Granger causality is found from the FTSE-100 to STOXX-600 Europe markets, and from the France CAC-40 to the London FTSE-100 market. The overall results implies that the US market is the leader and the Eurozone markets are the followers. In the case of Europe, German DAX-30 strongly affects the French Bourse CAC-40 and other Eurozone markets STOXX-600. This result is also not surprising given the high growth rates of Germany and France during the sample period of this study, and the impact of the UK's withdrawal from the EU (BREXIT).

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Appendix of Table 2: ADF Unit Root Test

US Market S&P500
Null Hypothesis: Sp500 Has A Unit Root

Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=25)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.123810	0.9450
Test critical values:	1% level	-3.433355	
	5% level	-2.862754	
	10% level	-2.567462	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(SP500) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=25)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-46.75554	0.0001
Test critical values:	1% level	-3.433357	
	5% level	-2.862755	
	10% level	-2.567463	

STOXX-600 EUROPE
Null Hypothesis: STOXX600 has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=25)

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                                               t-Statistic   Prob.*
====================================================================
Augmented Dickey-Fuller test statistic         -1.987539    0.2925
--------------------------------------------------------------------
Test critical
values:               1% level                 -3.433306
                      5% level                 -2.862732
                      10% level                -2.567451
====================================================================
```

```
Null Hypothesis: D(STOXX600) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=25)
====================================================================
                                               t-Statistic   Prob.*
====================================================================
Augmented Dickey-Fuller test statistic         -43.62889    0.0001
--------------------------------------------------------------------
Test critical
values:               1% level                 -3.433320
                      5% level                 -2.862738
                      10% level                -2.567454
====================================================================
*MacKinnon (1996) one-sided p-values.
```

UK FTSE-100

Null Hypothesis: FTSE100 has a unit root

```
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=25)
====================================================================
                                               t-Statistic   Prob.*
====================================================================
Augmented Dickey-Fuller test statistic         -2.397979    0.1424
--------------------------------------------------------------------
Test critical
values:               1% level                 -3.433401
                      5% level                 -2.862774
                      10% level                -2.567473
====================================================================
*MacKinnon (1996) one-sided p-values.
```

Null Hypothesis: D(FTSE100) has a unit root

```
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=25)
====================================================================
                                               t-Statistic   Prob.*
====================================================================
```

```
Augmented Dickey-Fuller test statistic     -31.71194   0.0000
______________________________________________________________
Test critical
values:              1% level              -3.433521
                     5% level              -2.862827
                    10% level              -2.567502
==============================================================
*MacKinnon (1996) one-sided p-values.
```

GERMAN DAX-30

Null Hypothesis: DAX30 has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=25)

```
==============================================================
                                          t-Statistic   Prob.*
==============================================================
Augmented Dickey-Fuller test statistic     -0.968520   0.7662
______________________________________________________________
Test critical
values:              1% level              -3.433328
                     5% level              -2.862742
                    10% level              -2.567456
==============================================================
*MacKinnon (1996) one-sided p-values.
```

Null Hypothesis: D(DAX30) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=25)

```
==============================================================
                                          t-Statistic   Prob.*
==============================================================
Augmented Dickey-Fuller test statistic     -44.25906   0.0001
______________________________________________________________
Test critical
values:              1% level              -3.433329
                     5% level              -2.862742
                    10% level              -2.567456
==============================================================
*MacKinnon (1996) one-sided p-values.
```

FRANCE CAC-40

Null Hypothesis: CAC40 has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=25)

```
==============================================================
                                          t-Statistic   Prob.*
==============================================================
```

```
Augmented Dickey-Fuller test statistic     -1.959208   0.3052
Test critical
values:             1% level               -3.433302
                    5% level               -2.862730
                   10% level               -2.567450

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(CAC40) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=25)

                                           t-Statistic   Prob.*

Augmented Dickey-Fuller test statistic     -44.88296   0.0001
Test critical
values:             1% level               -3.433303
                    5% level               -2.862731
                   10% level               -2.567450

*MacKinnon (1996) one-sided p-values.
```

Appendix of Table 3:
Johansen Cointegration Results

Sample (adjusted): 5 2042
Included observations: 1828 after adjustments
Trend assumption: No deterministic trend
Series: SP500 STOXXEU FTSE100 DAX CAC40
Lags interval (in first differences): 1 to 3

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.033897	116.8285	60.06141	0.0000
At most 1 *	0.017439	53.79005	40.17493	0.0013
At most 2	0.009125	21.62966	24.27596	0.1040
At most 3	0.002594	4.871778	12.32090	0.5856
At most 4	6.78E-05	0.124022	4.129906	0.7717

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.033897	63.03846	30.43961	0.0000
At most 1 *	0.017439	32.16040	24.15921	0.0033
At most 2	0.009125	16.75788	17.79730	0.0711
At most 3	0.002594	4.747756	11.22480	0.5135
At most 4	6.78E-05	0.124022	4.129906	0.7717

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Appendix of Table 4:
Pairwise Granger Causality Tests

Sample: 1 2092
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
STOXXEU does not Granger Cause SP500	2023	0.00044	0.9832
SP500 does not Granger Cause STOXXEU		6.81561	0.0091

FTSE100 does not Granger Cause SP500	1972	0.39228	0.5312
SP500 does not Granger Cause FTSE100		0.52941	0.4669
DAX does not Granger Cause SP500	2041	1.31759	0.2512
SP500 does not Granger Cause DAX		33.3120	9.E-09
CAC40 does not Granger Cause SP500	2041	0.39340	0.5306
SP500 does not Granger Cause CAC40		8.35845	0.0039
FTSE100 does not Granger Cause STOXXEU	1994	3.68681	0.0550
STOXXEU does not Granger Cause FTSE100		0.54765	0.4594
DAX does not Granger Cause STOXXEU	2041	13.1753	0.0003
STOXXEU does not Granger Cause DAX		2.51657	0.1128
CAC40 does not Granger Cause STOXXEU	2058	26.3626	3.E-07
STOXXEU does not Granger Cause CAC40		1.10028	0.2943
DAX does not Granger Cause FTSE100	1988	0.43175	0.5112
FTSE100 does not Granger Cause DAX		0.99806	0.3179
CAC40 does not Granger Cause FTSE100	2005	1.56987	0.2104
FTSE100 does not Granger Cause CAC40		1.77545	0.1829
CAC40 does not Granger Cause DAX	2059	2.26799	0.1322
DAX does not Granger Cause CAC40		13.4106	0.0003

Sample: 1 2092
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
STOXXEU does not Granger Cause SP500	2014	0.52315	0.5927
SP500 does not Granger Cause STOXXEU		4.16542	0.0157
FTSE100 does not Granger Cause SP500	1937	0.10930	0.8965
SP500 does not Granger Cause FTSE100		0.22526	0.7983

DAX does not Granger Cause SP500	2040	0.96641	0.3806
SP500 does not Granger Cause DAX		17.3995	3.E-08
CAC40 does not Granger Cause SP500	2040	0.54038	0.5826
SP500 does not Granger Cause CAC40		4.71109	0.0091
FTSE100 does not Granger Cause STOXXEU	1950	2.60576	0.0741
STOXXEU does not Granger Cause FTSE100		0.69256	0.5004
DAX does not Granger Cause STOXXEU	2032	6.65126	0.0013
STOXXEU does not Granger Cause DAX		1.61516	0.1991
CAC40 does not Granger Cause STOXXEU	2049	12.9716	3.E-06
STOXXEU does not Granger Cause CAC40		0.64242	0.5261
DAX does not Granger Cause FTSE100	1952	0.19190	0.8254
FTSE100 does not Granger Cause DAX		0.73943	0.4775
CAC40 does not Granger Cause FTSE100	1969	2.85533	0.0578
FTSE100 does not Granger Cause CAC40		1.18933	0.3046
CAC40 does not Granger Cause DAX	2058	2.55315	0.0781
DAX does not Granger Cause CAC40		6.72671	0.0012

Sample: 1 2092
Lags: 3

Null Hypothesis:	Obs	F-Statistic	Prob.
STOXXEU does not Granger Cause SP500	2005	0.54229	0.6534
SP500 does not Granger Cause STOXXEU		3.02711	0.0285
FTSE100 does not Granger Cause SP500	1902	0.61807	0.6033
SP500 does not Granger Cause FTSE100		0.28649	0.8352
DAX does not Granger Cause SP500	2039	0.54477	0.6517
SP500 does not Granger Cause DAX		12.0507	8.E-08

CAC40 does not Granger Cause SP500	2039	0.54274	0.6531
SP500 does not Granger Cause CAC40		3.67826	0.0117
FTSE100 does not Granger Cause STOXXEU	1906	1.95236	0.1192
STOXXEU does not Granger Cause FTSE100		2.06911	0.1023
DAX does not Granger Cause STOXXEU	2023	33.3918	5.E-21
STOXXEU does not Granger Cause DAX		1.15861	0.3242
CAC40 does not Granger Cause STOXXEU	2040	12.3333	5.E-08
STOXXEU does not Granger Cause CAC40		2.77791	0.0399
DAX does not Granger Cause FTSE100	1916	0.23956	0.8688
FTSE100 does not Granger Cause DAX		0.64406	0.5867
CAC40 does not Granger Cause FTSE100	1933	2.85459	0.0360
FTSE100 does not Granger Cause CAC40		0.77982	0.5052
CAC40 does not Granger Cause DAX	2057	2.28963	0.0765
DAX does not Granger Cause CAC40		40.5091	2.E-25

Sample: 1 2092
Lags: 4

Null Hypothesis:	Obs	F-Statistic	Prob.
STOXXEU does not Granger Cause SP500	1996	0.70252	0.5902
SP500 does not Granger Cause STOXXEU		2.59858	0.0346
FTSE100 does not Granger Cause SP500	1870	1.86590	0.1138
SP500 does not Granger Cause FTSE100		0.20324	0.9367
DAX does not Granger Cause SP500	2038	0.56631	0.6871
SP500 does not Granger Cause DAX		10.9664	8.E-09
CAC40 does not Granger Cause SP500	2038	0.50879	0.7293

SP500 does not Granger Cause CAC40		2.87917	0.0216
FTSE100 does not Granger Cause STOXXEU	1865	1.66346	0.1559
STOXXEU does not Granger Cause FTSE100		1.71005	0.1451
DAX does not Granger Cause STOXXEU	2014	25.3809	2.E-20
STOXXEU does not Granger Cause DAX		1.06580	0.3719
CAC40 does not Granger Cause STOXXEU	2031	11.2728	5.E-09
STOXXEU does not Granger Cause CAC40		2.93898	0.0195
DAX does not Granger Cause FTSE100	1883	0.26789	0.8987
FTSE100 does not Granger Cause DAX		0.57122	0.6836
CAC40 does not Granger Cause FTSE100	1900	2.16494	0.0706
FTSE100 does not Granger Cause CAC40		0.66463	0.6166
CAC40 does not Granger Cause DAX	2056	1.98960	0.0935
DAX does not Granger Cause CAC40		30.0474	3.E-24

Sample: 1 2092
Lags: 5

Null Hypothesis:	Obs	F-Statistic	Prob.
STOXX600 does not Granger Cause SP500	1987	0.63259	0.6749
SP500 does not Granger Cause STOXX600		2.77792	0.0166
FTSE00 does not Granger Cause SP500	1838	1.68812	0.1342
SP500 does not Granger Cause FTSE00		0.40389	0.8464
DAX30 does not Granger Cause SP500	2037	0.42040	0.8348
SP500 does not Granger Cause DAX30		8.81424	3.E-08
CAC40 does not Granger Cause SP500	2037	0.45218	0.8119
SP500 does not Granger Cause CAC40		2.41194	0.0343

Islam

FTSE00 does not Granger Cause STOXX600	1824	2.09687	0.0631
STOXX600 does not Granger Cause FTSE00		1.59289	0.1588
DAX30 does not Granger Cause STOXX600	2005	22.1241	1.E-21
STOXX600 does not Granger Cause DAX30		1.17610	0.3184
CAC40 does not Granger Cause STOXX600	2022	8.60695	4.E-08
STOXX600 does not Granger Cause CAC40		2.40947	0.0345
DAX30 does not Granger Cause FTSE00	1850	0.36327	0.8739
FTSE00 does not Granger Cause DAX30		0.60180	0.6986
CAC40 does not Granger Cause FTSE00	1867	1.89524	0.0921
FTSE00 does not Granger Cause CAC40		0.74297	0.5913
CAC40 does not Granger Cause DAX30	2055	1.59966	0.1569
DAX30 does not Granger Cause CAC40		27.5198	5.E-27