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Testing the Causality and Cointegration between the Performance of Euronext Stock Exchange Indexes
Standard Study for the Period (Jan 2010 ~ Jan 2021)

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Abstract:

The aim of this study is to test the causality and cointegration between the Euronext stock exchange performance indexes. However, for attainment purpose of this goal, we conducted a standard study on the (25AEX, CAC40, PSI20 and BEL20) indexes during the period spanning from January 2010 to June 2021. In virtue of which, the results of the conducted study indicate that the VAR model is dynamically stable, and stands for a strong model. More to the point, it was also found through the Granger causality test that there is a bidirectional reciprocal causal relationship between the CAC40 and the AEX25 indexes, as both indexes cause each other, whilst the causal relationship between the AEX25 and BEL20 indexes was a unidirectional causal relationship from AEX25 index to BEL20 index. In addition, the causal relationship between the CAC40 and BEL20 indexes has shown to be a unidirectional causal relationship from CAC40 index to BEL20 index. More to the point, the results have alike demonstrated that there is no bidirectional causal relationship between the PSI20 and AEX25 indexes, between the PSI20 and CAC40 indexes, and between the PSI20 and BEL20 indexes; in other words, no index causes the other. Nonetheless, it was found, through the response and reaction function that causing a random shock in the AEX25 index directly and inversely affects the AEX25, CAC40, PSI20 and BEL20 indexes; likewise, causing a random shock in the CAC40 index inversely affects the AEX25, CAC40, PSI20 and BEL20 indexes. Similarly, it was found that causing a random shock in the PSI20 index inversely affects the AEX25, PSI20 and BEL20 indexes, and inconstantly affects CAC40 index. In addition, causing a random shock in the PSI20 index adversely affects the AEX25 index, and inconstantly affects the CAC40, PSI20 and BEL20 indexes. Nevertheless, it turned out, through analyzing the variance components, that the two indexes AEX25 and CAC40 explain a large percentage of variance in the AEX25 index, and that the two indexes AEX25 and CAC40 explain a large percentage of variance in the CAC40 index; more and more, it turned out that the AEX25, CAC40 and PSI20 indexes explain a large percentage of variance in the PSI20 index, and that the two indexes AEX25 and BEL20 explain a large percentage of variance in the index CAC40.

First: Introduction

Indeed, Euronext is a European electronic stock exchange based in Amsterdam, with branches in Belgium, France, the Netherlands, Portugal and the United Kingdom. Moreover, in December 2010, Euronext was formed on the 22nd of September 2000 from the merger of the Amsterdam Stock Exchange, the Brussels Stock Exchange and the Paris Stock Exchange for the purpose of benefiting from the integration of the European Union and financial markets. In December 2001, Euronext owned and acquired the shares of the London International Financial Futures and Options Exchange, offering derivatives and spot markets. On the other hand, Euronext group provides market data, custody services, settlement and market solutions in addition to some other products including Exchange-Traded Funds (ETFs), shares, bonds, notes, certificates, goods and indexes. Furthermore, the stock exchange manages several European shares' indexes, in respect such as: AEX, BEL 20, CAC 40 and PSI 20. As consequence, this study was conducted to look for cointegration between the indexes of this stock exchange.

The study problem:
This study seeks in particular to study the causal relationship and cointegration between the Euronext indexes, all the way through targeting 04 main indexes. In light of which, study problem can be posed as follows: **Is there a causality and**

cointegration between the returns of the Euronext indexes during the period spanning from January 2010 to June 2021?

1) **The study hypotheses**:

Based on the reality of transactions in the European financial markets, the study starts from the main hypothesis that: "**There is a causality and cointegration between Euronext indexes during the period spanning from January 2010 to June 2021**", whereat they can be divided into the hypotheses listed hereunder, as follows:

1. **First Hypothesis**: There is a causality and cointegration between the AEX25 index performance and the BEL20 index performance during the period spanning from January 2010 to June 2021;

2. **Second Hypothesis**: There is a causality and cointegration between the AEX25 index performance and the CAC40 index performance during the period spanning from January 2010 to June 2021;

3. **Third Hypothesis**: There is a causality and cointegration between the BEL20 index performance and the CAC40 index performance during the period spanning from January 2010 to June 2021;

4. **Forth Hypothesis**: There is a causality and cointegration between the AEX25 index performance and the PSI20 index performance during the period spanning from January 2010 to June 2021;

5. **Fifth Hypothesis**: There is a causality and cointegration between the PSI20 index performance and the BEL20 index performance during the period spanning from January 2010 to June 2021;

6. **Sixth Hypothesis**: There is a causality and cointegration between the PSI20 index performance and the CAC40 index performance during the period spanning from January 2010 to June 2021.

2) **The study objectives**:

In point of fact, the aim of this research is to study the causality and cointegration between the Euronext stock exchange indexes, through targeting 04 main indexes. In this respect, we adopted the movement of indexes during the period together with their degree of volatility, whereat the study-traced objectives can be affirmed in some details to provide a descriptive analysis of financial indexes along with determining the degree of fluctuation during the study period, provide a comparative analysis in terms of the studied financial indexes in addition to analyzing the response and reaction function between the studied indexes and the impact of causing random shocks and analysis the variance components of financial indexes and the explanatory relationship between them during the study period.

Secondly: **Previous studies**

1. Study: Marcel Fratzscher 2002

This paper analyses the integration process of European equity markets since the 1980s. Its central focus is on the role that EMU, and specifically, changes in exchange rate volatility, has played in this process of financial integration. Building on an uncovered interest rate parity condition to measure financial integration, a trivariate GARCH model with time-varying coefficients yields three key results: first, European equity markets have become highly integrated only since 1996. Second, the Euro area market has gained considerably in importance in world financial markets and has taken over from the USA as the dominant market in Europe. Third, the integration of European equity markets is in large part explained by the drive towards EMU, and in particular the elimination of exchange rate volatility and uncertainty in the process of monetary unification.

2. Study: Robert Johnson and Luc Soenen (2003)

Using daily returns from 1988 through 1999 for Argentina, Brazil, Chile, Mexico, and Canada, and from 1993 to 1999 for Colombia, Peru and Venezuela, investigate to what degree these equity markets are integrated with the US equity market and examine the factors that affect the level of economic integration. We find a statistically significant high percentage of contemporaneous association between the eight equity markets of the Americas and the stock market in the United States. A high share of trade with the United States has a strong positive effect on stock market comovements.

Conversely, increased bilateral exchange rate volatility and a higher ratio of stock market capitalization relative to that of the United States contribute to lower comovement.

3. Study: Serwa,. Bohl (2005)

This paper investigates contagion to European stock markets associated with seven big financial shocks between 1997 and 2002. We apply methods using heteroscedasticity-adjusted correlation coefficients to discriminate between contagion, interdependence and breaks in stock markets relationships. The analysis focuses on a comparison between developed Western European markets and emerging stock markets in Central and Eastern Europe. We find modest evidence of significant instabilities in cross-market linkages after the crises. The Central and Eastern European stock markets are not more vulnerable to contagion than Western European markets.

4. -Study: Ilhan Meric (2009)

This study aimed to test the joint movements of both US and Canadian stock market returns
And Mexican through correlation analysis and Granger causality techniques during the period June 1995 to As of May 2005, the results of the analysis showed that the correlation of US market returns with Canadian and Mexican stock market returns was high and that the profits of US investors' portfolios among the NAFTA1 countries had decreased. As for the Lee Cranger causality results, they showed that past returns in the Canadian stock market could be used to forecast. The results of the market efficiency test showed that the returns for the three NAFTA stock markets follow the random walk method, and that the historical returns for each of these markets can be used to predict future returns.

5. Study: Francisco Herrera (2012)

This paper analyzes the first generation of integration between the stock markets of Mexico; Canada; And the states In the United States of America and the integration of these markets with the global market, the data for this study was formed from historical prices extracted from the International Capital Stanley Morgan Index for monthly series. Multivariate Johansen cointegration tests were conducted from 1984 to 2002, and this period was divided into two stages to study cointegration before and after the implementation of NAFTA. A bivariate cointegration test was also conducted. The experimental results showed that the Mexican, Canadian, and United States stock markets were partially sep

6. -Study: Mellado and Diego Escobari (2015)

This article investigates the role of virtual integration of financial markets on stock market return co-movements. In May of 2011, the Chilean, Colombian and Peruvian stock markets virtually integrated their stock exchanges and central securities depositories to form the Latin American Integrated Market (MILA). utilize the dynamic conditional correlation model proposed by Engle (2002) to identify a statistically significant positive correlation between these markets. Moreover, find strong evidence that the creation of the MILA increased the levels of dynamic correlation between stock returns. A higher correlation was also found during the dot-com bubble and the 2007 financial crises. results imply a decline in gains from international diversification by holding portfolios consisting of diverse stocks of these countries.

7. Study: Olbryś and Majewska (2015)

The main goal of this paper is to explicitly test a research hypothesis that there was no integration effect among the U.S. and the eight Central and Eastern European (CEE) stock markets during the 2007–2009 Global Financial Crisis (GFC). As growing international integration could lead to a progressive increase in cross-market correlations, the evaluation of integration was carried out by applying equality tests of correlation matrices computed over non-overlapping subsamples: the pre-crisis and crisis periods, in the group of investigated markets. The crisis periods are formally established based on a statistical method of dividing market states into bullish and bearish markets. The sample period May 2004–April 2014 includes the 2007 U.S. subprime financial crisis. The robustness analysis of the integration tests with respect to various data frequencies is provided. The empirical results are not homogeneous and they depend both on the integration test and data frequency. Consequently, it is not possible to conclude whether integration between the investigated markets is present.

Thirdly: **Field study**

1) **The study sample**:

The study community consists of the Euronext stock exchange indexes, under form of: AEX25 index, CAC40 index, BEL20 index and PSI20 index, depending on the volume of their exchanges and currencies, and in line with the study objectives. Besides, this sample consisting of 04 main indexes was selected based on the availability of data of the selected indexes for our study during the target period, as the study data were obtained from several sources, the most important of which is the "Investing.com" website, together with the studied financial market websites.

2) Study of the research variables' stability

By the stability of a time series, we mean the fluctuation of its data around a constant mean of the series and the absence of change in its variance. Moreover, several tests are carried out to clarify whether the series is constant or not; nonetheless, the most widely-known of which is the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test. Nevertheless, since the random process may include the constant term or time trend, there are three different forms of tests, as per illustrated in the following table:

Table No.01: Results of the research variables' stability study

Variable	Test	Level			First difference		
		Test with constant term	Test with constant term and trend	Test without constant term and without trend	Test with constant term	Test with constant term and trend	Test without constant term and without trend
AEX25	**ADF**	0.360042) 0.9805(	-2.478486)0.3383(	1.880232)0.9855(	-11.68278)0.0000(	-11.75692	-11.42244)0.0000(
	PP	0.570149)0.9885(	-2.478486)0.3383(	2.08921)0.9912(	-11.69494)0.0000(	-11.40415)0.0000(	-11.42048)0.0000(
CAC40	**ADF**	-0.703623) 0.8413(	-3.008442)0.1338(	0.987396)0.9141(	-11.38942)0.0000(	-11.75692)0.0000(	-11.32495)0.0000(
	PP	-0.670586)0.8495(	-3.131696)0.1032(	1.085292)0.9272(	-11.39706)0.0000(	-11.41694)0.0000(	-11.32096)0.0000(
BEL20	**ADF**	-1.165091)0.6883(	-2.421784)0.3667(	0.784752)0.8814(	-11.81352)0.0000(	-11.77682)0.0000(	-11.76798)0.0000(
	PP	-1.050323)0.7339(	-2.380632)0.3880(	0.960410)0.9102(	-11.89026)0.0000(	-11.84769)0.0000(	-11.81477)0.0000(
PSI20	**ADF**	-2.360847)0.1549(	-2.773305)0.2098(	-1.250303)0.1935(	-10.68001)0.0000(	-10.67491)0.0000(	-10.68229)0.0000(
	PP	-2.551076)0.1059(	-2.940233)0.1534(	-1.206604)0.2077(	-10.68887)0.0000(	-10.68381)0.0000(	-10.68323)0.0000(

Source: Prepared by the researcher based on the Eviews program outputs.

In the light of the Table No.01, upon application of the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test, it has shown that the time series of AEX25, CAC40, BEL20 PSI20 indexes are constant at the first difference, whilst they are integrated of order one (1)I; i.e., there is a possibility of cointegration between these indexes.

3) Determination of the optimal time lag

For determination purpose of the length of distributed time lags, we use several criteria, as per illustrated in the following table:

Table No.02: Results of the optimal time lag determination

Lag	LogL	LR	FPE	AIC	SC	HQ

0	-3420.926	NA	4.79e+13	54.36391	54.45395	54.40049
1	-2796.644	1199.019	3.07e+14*	44.70363*	45.15333*	44.39153*
2	-2733.713	24.01379	3.22e+14	44.75735	45.56772	45.03653
3	-2776.378	13.15752	3.71e+14	44.39433	46.06541	45.37043
4	-2763.150	22.33526	3.39e+14	44.93339	46.46959	45.56077
5	-2754.978	13.62028	4.43 e+14	45.06315	46.95400	45.33134
6	-2745.579	15.06395	4.96e+14	45.16792	47.41393	46.03243
7	-2731.363	21.33734	5.17e+14	45.19624	47.30742	46.25703
8	-2721.914	13.94916	5.33e+14	45.30022	43.27156	46.50733
9	-2702.382	26.38530*	5.67e+14	45.25210	43.53361	46.60559
10	-2691.551	15.23736	6.23e+14	45.32621	49.01733	46.32602
11	-2630.135	14.67753	6.93e+14	45.39393	49.45031	47.04511
12	-2661.721	22.50659	7.00e+14	45.36065	49.77264	47.15311

Source: Prepared by the two researchers based on the Eviews 9 program outputs.

In the light of the Table No.02, according to the selection standards of the optimal time lag, it has shown that the Lag = 1 is the optimal time lag for estimation purpose of the Vector Autoregressive (VAR) model.

Fourthly: **Cointegration test**
Upon conducting the Johansen test on the Vector Autoregressive (VAR) model (1), since the acceptable lag degree is P = 1, we found that:

Table No.03: Johansen test for the cointegration between indexes

Unrestricted Cointegration RankTest (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.172960	37.42599	47.85613	0.3277
At most 1	0.0614-04	11.59932	29.79707	0.9449
At most 2	0.020281	2.981016	15.49471	0.9678
At most 3	O 001429	0.194501	3.841466	0.6592

Trace test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
** MacKinnon-Haug-Michelis (1999) p-values

Source: Prepared by the researcher based on the Eviews 9.0 program outputs.

In the light of the Table No.03, we note that the Trace Statistic (37.42599) is smaller than the Critical Value (47.85613) at a significance level of 05% in the case of Non; the same applies for the case of "At most 1", whereat the Trace Statistic (11.59932) was smaller than the Critical Value (29.79707); with regards to the case of "At most 2", the Trace Statistic (2.981016) was smaller than the Critical Value (15.49471); however, in the case of "At most 3", the Trace Statistic (0.194501) was smaller than the Critical Value (3.841466), At a significance level of 05%. In virtue of which, this means accepting the null hypothesis of "there is no cointegration between the indexes".

4) The Vector Autoregressive (VAR) model estimation results
In the light of the Vector Autoregressive (VAR) model estimation results, it turns out that:

1. **With regards to the AEX25 index equation**:

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$$\boldsymbol{AEX25_t = 38.477 + 1.231 * AEX25_{t-1} - 0.034 * CAC40_{t-1} + 0.0004 * PSI20_{t-1} + 0.005 * BEL20_{t-1}}$$

(-2.2894) (0.1658-) (0.5525) (2.2701) (13.2896)

$$R^2 = 0.9713 \qquad F_{STAT} = 1116.89 \qquad (.): t - statistic \qquad n = 137$$

Based on the results of the AEX25 index equation, we note that:

- The parameters of the two indexes $AEX25_{t-1}$ and $CAC40_{t-1}$, in addition to the constant term, have a statistical significance, since the calculated values of the Student statistic with the absolute value have shown to be completely bigger than the scheduled value 1.96 at a 05% level, the fact of which indicates that the $AEX25_{t-1}$ index for the previous month directly affects the $AEX25_{t-1}$ index of the current month. Moreover, the $CAC40_{t-1}$ index of the previous month indirectly affects the $CAC40_t$ index of the current month.

- The parameters of the two indexes $PSI20_{t-1}$ and $BEL20_{t-1}$ have no statistical significance, since the calculated values of the Student statistic with the absolute value have shown to be completely smaller than the scheduled value 1.96 at a 05% level, the fact of which indicates that the $PSI20_{t-1}$ and $BEL20_{t-1}$ two indexes for the previous month do not affect the $AEX25_t$ index of the current month.

- There is high quality for the consistency and integration since the $R^2 = 0.9713$, which means that the $AEX25_{t-1}$, $CAC40_{t-1}$, $PSI20_{t-1}$ and $BEL20_{t-1}$ indexes of the previous month explain the $AEX25_t$ index for the current month by 97.13%.

- The model has a complete statistical significance since the Fisher statistic equal to $F_{STAT} = 1116.89$ is completely bigger than the scheduled value of Fisher distribution F(4,133,0.05) = 2.37. As consequence, the model as a whole is statistically acceptable.

2. **With regards to the CAC40 index equation**:

$$\boldsymbol{CAC40_t = 327.325 + 3.698 * AEX25_{t-1} - 0.433 * CAC40_{t-1} + 0.024 * PSI20_{t-1} + 0.145 * BEL20_{t-1}}$$

(2.2500) (0.8249) (1.3909) (1.6774) (3.4668)

$$R^2 = 0.9365 \qquad F_{STAT} = 487.15 \qquad (.): t - statistic \qquad n = 137$$

Based on the results of the CAC40 index equation, we note that:

- The parameters of the two indexes $AEX25_{t-1}$ and $CAC40_{t-1}$ have a statistical significance, since the calculated values of the Student statistic with the absolute value have shown to be completely bigger than the scheduled value 1.96 at a 05% level, the fact of which indicates that the two indexes $AEX25_{t-1}$ and $CAC40_{t-1}$ for the previous month directly affect the $CAC40_t$ index of the current month.

- The parameters of the two indexes $PSI20_{t-1}$ and $BEL20_{t-1}$, in addition to the constant term, have no statistical significance, since the calculated values of the Student statistic with the absolute value have shown to be completely smaller than the scheduled value 1.96 at a 05% level, the fact of which indicates that the two indexes $PSI20_{t-1}$ and $BEL20_{t-1}$ for the previous month do not affect the $CAC40_t$ index of the current month.

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- There is high quality for the consistency and integration since the $\square^2 = 0.9365$, which means that the $AEX25_{t-1}$, $CAC40_{t-1}$, $PSI20_{t-1}$ and $BEL20_{t-1}$ indexes of the previous month explain the $CAC40_t$ index for the current month by 93.65%.

- The model has a complete statistical significance since the Fisher statistic equal to $F_{STAT} = 487.15$ is completely bigger than the scheduled value of Fisher distribution F(4,133,0.05) = 2.37. As consequence, the model as a whole is statistically acceptable.

3. **With regards to the PSI20 index equation**:

$$\boldsymbol{PSI20_t = 508.474 + 1.367 * AEX25_{t-1} - 0.233 * CAC40_{t-1} + 0.955 * PSI20_{t-1} + 0.051 * BEL20_{t-1}}$$

(**-0.9921**) (**23.3437**) (**0.3544**) (**1.8873**) (**0.9278**)

$R^2 = 0.9186$ $F_{STAT} = 372.47$ $(.): t - statistic$ $n = 137$

Based on the results of the PSI20 index equation, we note that:

- The parameters of the index $PSI20_{t-1}$ has a statistical significance, since the calculated values of the Student statistic with the absolute value have shown to be completely bigger than the scheduled value 1.96 at a 05% level, the fact of which indicates that the $PSI20_{t-1}$ index for the previous month directly affects the $PSI20_t$ index of the current month.
- The parameters of the $AEX25_{t-1}$, $CAC40_{t-1}$ and $BEL20_{t-1}$ indexes, in addition to the constant term, have no statistical significance, since the calculated values of the Student statistic with the absolute value have shown to be completely smaller than the scheduled value 1.96 at a 05% level, the fact of which indicates that the $AEX25_{t-1}$, $CAC40_{t-1}$ and $BEL20_{t-1}$ indexes for the previous month do not affect the $PSI20_t$ index of the current month.

- There is high quality for the consistency and integration since the $\square^2 = 0.9186$, which means that the $AEX25_{t-1}$, $CAC40_{t-1}$, $PSI20_{t-1}$ and $BEL20_{t-1}$ indexes of the previous month explain the $PSI20_t$ index for the current month by 91.86%.

- The model has a complete statistical significance since the Fisher statistic equal to $\square_{STAT} = 372.47$ is completely bigger than the scheduled value of Fisher distribution F(4,133,0.05) = 2.37. As consequence, the model as a whole is statistically acceptable.

4. **With regards to the BEL20 index equation**:

$$\boldsymbol{BEL20_t = 280.291 + 1.527 * AEX25_{t-1} - 0.226 * CAC40_{t-1} - 0.001 * PSI20_{t-1} + 1.025 * BEL20_{t-1}}$$

(**-2.0097**) (**-0.0687**) (**14.7783**) (**2.1667**) (**2.1598**)

$R^2 = 0.9468$ $F_{STAT} = 587.84$ $(.): t - statistic$ $n = 137$

Based on the results of the BEL20 index equation, we note that:

- The parameters of the two indexes $CAC40_{t-1}$ and $BEL20_{t-1}$, in addition to the constant term, have a statistical significance, since the calculated values of the Student statistic with the absolute value have shown to be completely bigger than the scheduled value 1.96 at a 05% level, the fact of which indicates that the $CAC40_{t-1}$ index for the previous month indirectly affects the $BEL20_t$ index of the current month, and that the $BEL20_{t-1}$ of the previous month directly affects the $BEL20_t$ of the current month.

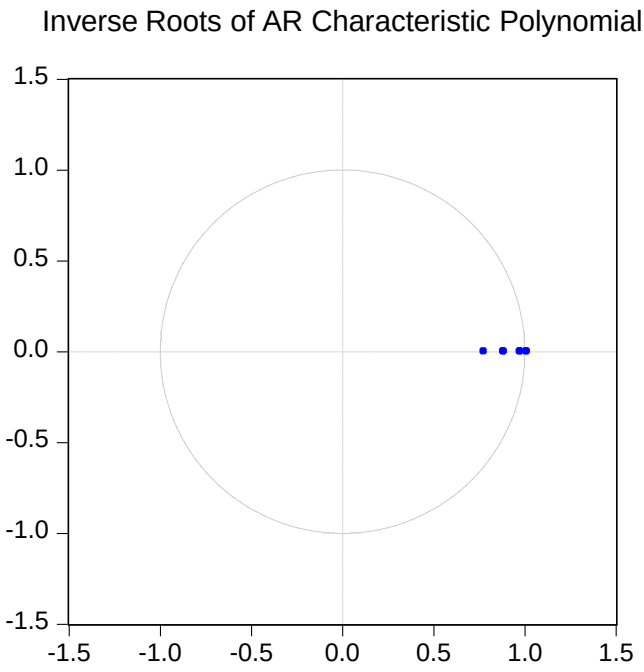
- The parameters of the two indexes $AEX25_{t-1}$ and $PSI20_{t-1}$ have no statistical significance, since the calculated values of the Student statistic with the absolute value have shown to be completely smaller than the scheduled value 1.96 at a 05% level, the fact of which indicates that the two indexes $AEX25_{t-1}$ and $PSI20_{t-1}$ for the previous month do not affect the $BEL20_t$ index of the current month.

- There is high quality for the consistency and integration since the $\square^2 = 0.9468$, which means that the $AEX25_{t-1}$, $CAC40_{t-1}$, $PSI20_{t-1}$ and $BEL20_{t-1}$ indexes of the previous month explain the $BEL20_t$ index for the current month by 94.68%.

- The model has a complete statistical significance since the Fisher statistic equal to $\square_{STAT} = 587.84$ is completely bigger than the scheduled value of Fisher distribution F(4,133,0.05) = 2.37. As consequence, the model as a whole is statistically acceptable.

5) **Dynamic stability test of the VAR model**:

Figure No.01: Drawing the roots of Autoregressive



Source: Prepared by the two researchers based on the Eviews 9 program outputs.

In the light of the Figure No.01, we note that the roots of Autoregressive are as a whole inside the unit circle which indicate that the VAR model is dynamically constant, which is a strong model.

6) Study of causality between variables

Table No.04: Granger Causality test

Dependent variable: AEX25

Excluded	Chi-sq	df	Prob.
CAC40	5.241465	1	0.0221
PSI20	0.027491	1	0.8683
BEL20	0.305314	1	0.5806
All	15.83642	3	0.0012

Dependent variable: PSI20

Excluded	Chi-sq	df	Prob.
AEX25	0.860901	1	0.3535
CAC40	0.984375	1	0.3211
BEL20	0.125643	1	0.7230
All	2.316870	3	0.5093

Dependent variable: CAC40

Excluded	Chi-sq	df	Prob.
AEX25	12.01877	1	0.0005
PSI20	0.680553	1	0.4094
BEL20	1.934641	1	0.1643
All	19.18725	3	0.0003

Dependent variable: BEL20

Excluded	Chi-sq	df	Prob.
AEX25	4.665000	1	0.0308
CAC40	4.039200	1	0.0445
PSI20	0.004722	1	0.9452
All	11.13295	3	0.0110

Source: Prepared by the two researchers based on the Eviews 9 program outputs.

Based on the Granger Causality test, it turns out that:

- **For the AEX25 index**: It turned out that the CAC40 index causes the AEX25 index because the probability value of the K-Do statistic Prob=0.0221 has shown to be less than 0.05, and that the two indexes BEL20 and PSI20 do not cause the AEX25 index, since the probability value of the K-Do statistic is respectively equal to 0.8683 and 0.5806 greater than 0.05 at a significance level of 05%.

- **For the CAC40 index**: It turned out that the AEX25 index causes the CAC40 index, because the probability value of the K-Do statistic Prob=0.0005 has shown to be less than 0.05, and that the two indexes BEL20 and PSI20 do not cause the CAC40 index, since the probability value of the K-Do statistic is respectively equal to 0.4094 and 0.1643 greater than 0.05 at a significance level of 05%.

- **For the PSI20 index**: It turned out that the AEX25, CAC40 and BEL20 indexes do not cause the PSI20 index, because the probability value of the K-Do statistic is respectively equal to 0.3535, 0.3211 and 0.7230 greater than 0.05 at a significance level of 05%.

- **For the BEL20 index**: It turned out that the two indexes AEX25 and CAC40 cause the BEL20 index, because the probability value of the K-Do statistic is respectively equal to 0.0308 and 0.0445 smaller than 0.05, and that the PSI20 index does not cause the BEL20 index, since the probability value of the K-Do statistic is equal to 0.9452 greater than 0.05 at a significance level of 05%.

7) Response and reaction functions

In accordance with the Appendix No.03, the graph of the response and reaction functions of the AEX25, CAC40, PSI20 and BEL20 indexes would possibly be analyzed upon causing a random shock of one single standard deviation amount in one of indexes hereunder:

1. **The response of indexes to a random shock effect in the AEX25 index**:

In fact, we note that the reactive response of the AEX25, CAC40, PSI20 and BEL20 indexes to a random shock effect of one single standard deviation in the AEX25 index comes into sight starting from the first month, and then begins with a positive gradual decrease until the tenth month.

2. **The response of indexes to a random shock effect in the CAC40 index**:

Actually, we note that the reactive response of the AEX25 index to a random shock effect of one single standard deviation in the CAC40 index comes into sight starting from the second month, and then begins with a negative gradual decrease until the tenth month. Moreover, the CAC40 index response appears starting from the first month, and then begins with a positive gradual decrease until such decrease becomes negative in the fourth month until the tenth month. Likewise, we note that the PSI20 index response appears starting from the first month, and then begins with a positive gradual decrease until the tenth month. In addition, the BEL20 index response appears starting from the first month, and then begins with a positive gradual decrease until the tenth month. More and more, the BEL20 index response appears starting from the first month and decreases positively until the third month, and then the response becomes negative starting from the fourth month until the tenth month.

3. **The response of indexes to a random shock effect in the PSI20 index**:

Indeed, the reactive response of the AEX25 index to a random shock effect of one standard deviation in the PSI20 index, comes into sight starting from the second month, and then decreases negatively until the tenth month. Moreover, the CAC40 index response appears starting from the second month, increases until the third month, then decreases positively until the sixth month, and then decreases negatively until the tenth month. Likewise, the PSI20 index response appears starting from the first month, and then begins with a positive gradual decrease until the tenth month. In addition, BEL20 index response appears starting from the tenth month, and then begins with a positive gradual decrease until the tenth month. More and more, the BEL20 index response comes into sight starting from the first month, and then decreases positively until the third month, seeing that the response becomes negative starting from the fourth month until the tenth month.

4. **The response of indexes to a random shock effect in the BEL20 index**:

In effect, the reactive response of the AEX25 index to the a random shock effect of one single standard deviation in the BEL20 index, appears positive starting from the second month until the third month, and then positively decreases until the response becomes negative starting from the sixth month to the tenth month. Moreover, the CAC40 index response comes into sight starting from the second month, increases positively until the fifth month, and then decreases positively until the tenth month. Likewise, we note that the PSI20 index response appears starting from the second month, increases positively until the fourth month, and then positively decreases until tenth month. With regards to the BEL20 index response, it appears starting from the first month and then begins to positively increase until the third month, and then positively decreases until the tenth month.

8) Analysis of the AEX25 index variance components

In accordance with the Appendix No.03, the variance components of the AEX25, CAC40, PSI20 and BEL20 indexes would possibly be analyzed, as follows:

1. **Analysis of the AEX25 index variance components**:

Remarkably, we note that the AEX25 Index explains 100% of the expected error variance in the first month when causing a shock by one single standard deviation in the same variable, and then gradually decreases to reach 70.46% after ten months. Furthermore, the interpretation percentage of the CAC40, PSI20 and BEL20 indexes for the variance in the AEX25 index, has shown to be absent in the first month, and then increases to reach 27.65%, 1.70% and 0.16%, respectively, after ten months.

2. **Analysis of the CAC40 index variance components**:

Unquestionably, we note that the interpretation percentage of the AEX25 index for the variance in the CAC40 index, has shown to be equal to 81.63% in the first month, increases to 91.08% in the fifth month, and then decreases until it reaches 84.47% after ten months. Moreover, the interpretation of the CAC40 index for the same index is equal to 18.36% in the first month, decreases until it reaches 08.30% in the fifth month, and then increases until it reaches 14.54% after ten months. Likewise, we note that interpretation of the PSI20 and BEL20 indexes for the CAC40 variance is absent in the first month, and then decreases by a weak percentage until it reaches 0.29% and 0.68%, respectively, in the tenth month.

3. **Analysis of the PSI20 index variance components**:

Categorically, we note that the interpretation percentage of the AEX25 and CAC40 indexes for the PSI20 variance, has shown to be equal to 41.07% and 47.12%, respectively, in the first month, and then continuously decreases until it reaches 34.08% and 59.77%, respectively, ten years later. More to the point, we alike note that the interpretation percentage of the PSI20 index, for the variance in the same index, is equal to 47.12% in the first month, and then continuously increases to reach 59.77% in the tenth month. With regards to the interpretation percentage of the BEL20 index, for the variance in the PSI20 index, it has shown to be null in the first month, and then decreases by a weak percentage until it reaches 0.01% in the tenth month.

4. **Analysis of the BEL20 index variance components**:

Emphatically, we note that the interpretation percentage of the AEX25 index, for the variance in the BEL20 index, has shown to be equal to 75.77% in the first month, and then decreases starting from the third month until it reaches 66.81% in the tenth month. Moreover, the interpretation percentage of the CAC40 index is equal to 08.34% in the first month, decreases to 03.35% in the fifth month, and then increases to 05.68% in the tenth month. Similarly, we alike note that the interpretation percentage of the PSI20 index, for the variance in the BEL20 index, has shown to be equal to 0.03% in the first month, and then decreases by a weak percentage until it reaches 01% in the tenth month. With regards to the interpretation of the BEL20 index, for the variance in the same index, it has shown to be equal to 15.08% in the first month, and then continuously increases to reach 26.49% ten months later.

Fourthly: **Conclusion**

In a consequence, this research paper addressed the causality and cointegration test between the performance of Euronext stock exchange indexes. However, for attainment purpose of this goal, we conducted a standard study on the AEX25, CAC40, PSI20 and BEL20 indexes, during the period spanning from January 2010 to June 2021. Subsequently, we reached through this standard study the results listed hereunder:

1. Results of the study hypotheses test

- **For the First Hypothesis**: We note that there is no bidirectional reciprocal causal relationship between the BEL20 and the AEX25 indexes, since the causal relationship between the AEX25 index and the BEL20 index was a unidirectional causal relationship from AEX25 index to BEL20 index. In virtue of which, this hypothesis was rejected, which states that: “There is a causality and cointegration between the AEX25 index performance and the BEL20 index performance during the period spanning from January 2010 to June 2021”.

- **For the Second Hypothesis**: We note that there is a bidirectional reciprocal causal relationship between the CAC40 and the AEX25 indexes, as both indexes cause each other. In virtue of which, this hypothesis was accepted, which states that: “There is a causality and cointegration between the AEX25 index performance and the CAC40 index performance during the period spanning from January 2010 to June 2021”.
- **For the Third Hypothesis**: We note that there is no bidirectional reciprocal causal relationship between the BEL20 and the CAC40 indexes, since the causal relationship between the CAC40 and BEL20 indexes was a unidirectional causal relationship from CAC40 index to BEL20 index. In virtue of which, this hypothesis was rejected, which states that: “There is a causality and cointegration between the BEL20 index performance and the CAC40 index performance during the period spanning from January 2010 to June 2021”.

- **For the Forth Hypothesis**: We note that there is no bidirectional reciprocal causal relationship between the PSI20 and the AEX25 indexes. In virtue of which, this hypothesis was rejected, which states that: "There is a causality and cointegration between the PSI20 index performance and the AEX25 index performance during the period spanning from January 2010 to June 2021".

- **For the Fifth Hypothesis**: We note that there is no bidirectional reciprocal causal relationship between the PSI20 and the BEL20 indexes. In virtue of which, this hypothesis was rejected, which states that: "There is a causality and cointegration between the PSI20 index performance and the BEL20 index performance during the period spanning from January 2010 to June 2021".

- **For the Sixth Hypothesis**: We note that there is no bidirectional reciprocal causal relationship between the PSI20 and the CAC40 indexes. In virtue of which, this hypothesis was rejected, which states that: "There is a causality and cointegration between the PSI20 index performance and the CAC40 index performance during the period spanning from January 2010 to June 2021".

2. **Results of the study**: We attained the results listed hereinafter:

- In accordance with the standard study of indexes, it figures out that the time series of the AEX25, CAC40, BEL20 and PSI20 indexes are stable at the first difference, and have shown to be integrated of order one (1)I.

- In accordance with the Johansen cointegration test, it turns out that there is no cointegration between the indexes; i.e., there is no relationship between the indexes in the long term.

In the light of the Vector Autoregressive (VAR) model estimation results, it turns out that:

- With regards to the AEX25 index equation, it figures that $AEX25_{t-1}$ index for the previous month directly affects the $AEX25_t$ index for the current month; the $CAC40_{t-1}$ index of the previous month indirectly affects the $AEX25_t$ index of the current month, and that the two indexes $PSI20_{t-1}$ and $BEL20_{t-1}$ for the previous month do not affect the $AEX25_t$ index for the current month, on the short term.
- With regards to the CAC40 index equation, it figures that the two indexes $AEX25_{t-1}$ and $CAC40_{t-1}$ for the previous month directly affect the $CAC40_t$ index for the current month; and that the two indexes $PSI20_{t-1}$ and $BEL20_{t-1}$ for the previous month do not affect the $CAC40_t$ index for the current month, on the short term.

- With regards to the PSI20 index equation, it figures that the $PSI20_{t-1}$ index for the previous month directly affects the $PSI20_t$ index for the current month; and that the $AEX25_{t-1}$, $CAC40_{t-1}$ and $BEL20_{t-1}$ indexes for the previous month do not affect the $PSI20_t$ index for the current month, on the short term.

- With regards to the BEL20 index equation, it figures that the $BEL20_{t-1}$ index for the previous month directly affects the $BEL20_t$ index for the current month; and that the two indexes $AEX25_{t-1}$ and $PSI20_{t-1}$ for the previous month do not affect the $BEL20_t$ index for the current month, on the short term.

- In the light of the response and reaction function, it figures out that causing a random shock in the AEX25 index inversely and adversely affects the 25AEX, CAC40, PSI20 and BEL20 indexes. More to the point, it alike figured out that causing a random shock in the CAC40 index adversely affects the 25AEX, CAC40, PSI20 and BEL20 indexes. In addition, it turns out that causing a random shock in the PSI20 index adversely affects the 25AEX, PSI20 and BEL20, and inconstantly affects the CAC40 index. More and more, causing a random shock in the PSI20 index adversely affects the AEX25 index, and inconstantly affects the CAC40, PSI20 and BEL20 indexes.

- Through analyzing the variance components, it figures out that the two indexes AEX25 and CAC40 explain a large percentage of variance in the AEX25 index, and that the two indexes AEX25 and CAC40 explain a large

percentage of variance in the CAC40 index. Additionally, it turned out that the AEX25, CAC40 and PSI20 indexes explain a large percentage of variance in the PSI20 index, and that the two indexes AEX25 and BEL20 explain a large percentage of variance in the index CAC40.

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Appendixes:

- Appendix No.01: Descriptive statistics of study variables

	AEX25	CAC40	PSI20	BEL20
Mean	452.0535	4551.987	5628.937	3199.421
Median	448.8500	4496.505	5357.615	3338.515
Maximum	733.1400	6622.870	8102.150	4179.930
Minimum	280.1800	2981.960	3945.120	2073.950
Std. Dev.	104.7715	810.0621	1003.677	587.5528
Observations	138	138	138	138

	AEX25	CAC40	BEL20	PSI20
AEX25	1	0.9697838349358082	0.8945524453892828	-0.5348995588190816
CAC40	0.9697838349358082	1	0.9402786290252516	-0.3972127521327998
BEL20	0.8945524453892828	0.9402786290252516	1	-0.4408423033431544
PSI20	-0.5348995588190816	-0.3972127521327998	-0.4408423033431544	1

-

- Appendix No.02: Results of the Vector Autoregressive (VAR) model estimation;

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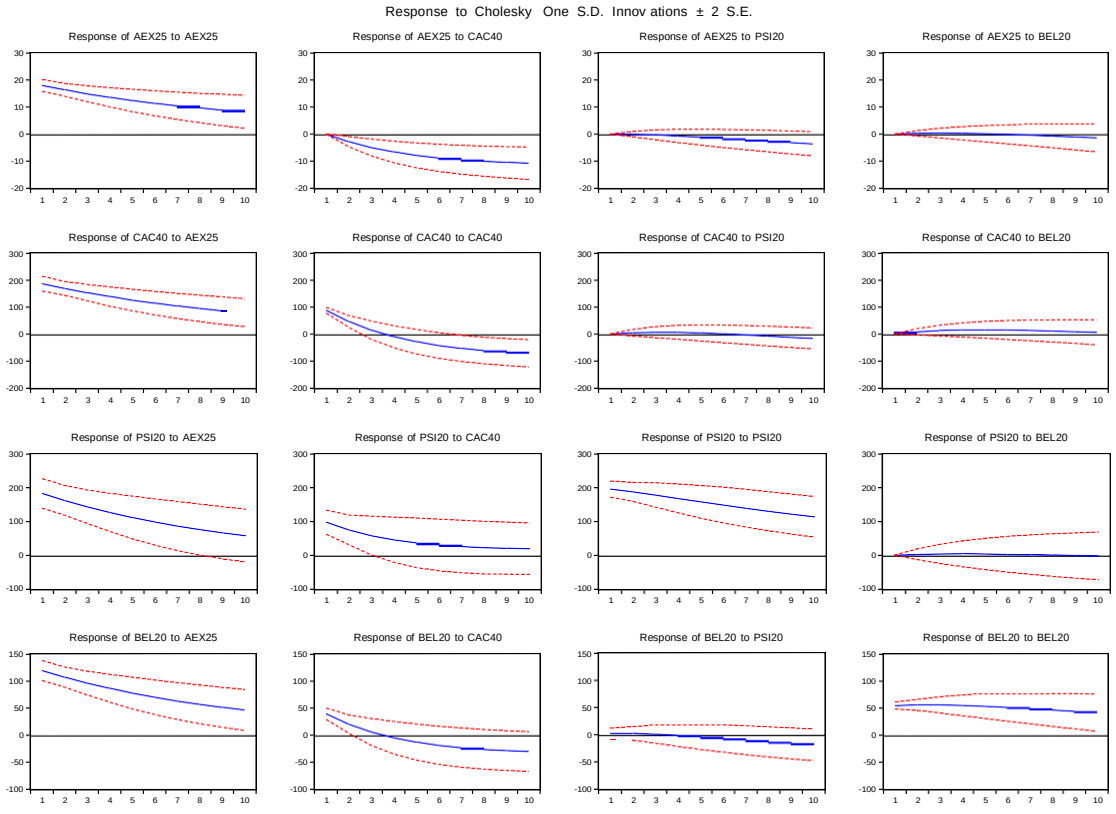
Vector Autoregression Estimates
Date: 07/07/21 Time: 20:39
Sample (adjusted): 2010M02 2021M06
Included observations: 137 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	AEX25	CAC40	PSI20	BEL20
AEX25(-1)	1.231249 (0.09265) [13.2896]	3.697785 (1.06663) [3.46681]	1.366861 (1.47315) [0.92785]	1.527258 (0.70711) [2.15986]
CAC40(-1)	-0.033768 (0.01475) [-2.28942]	0.433013 (0.16981) [2.55001]	-0.232688 (0.23453) [-0.99216]	-0.226246 (0.11257) [-2.00978]
PSI20(-1)	-0.000427 (0.00257) [-0.16580]	0.024442 (0.02963) [0.82496]	0.955220 (0.04092) [23.3437]	-0.001350 (0.01964) [-0.06871]
BEL20(-1)	0.005020 (0.00908) [0.55255]	0.145472 (0.10459) [1.39091]	0.051202 (0.14445) [0.35446]	1.024658 (0.06934) [14.7784]
C	38.47673 (16.9492) [2.27013]	327.3252 (195.131) [1.67746]	508.6479 (269.502) [1.88736]	280.2914 (129.360) [2.16675]
R-squared	0.971302	0.936558	0.918614	0.946847
Adj. R-squared	0.970432	0.934635	0.916147	0.945236
Sum sq. resids	42712.59	5661242.	10799001	2488064.
S.E. equation	17.98834	207.0947	286.0255	137.2915
F-statistic	1116.895	487.1575	372.4738	587.8489
Log likelihood	-587.7399	-922.4929	-966.7309	-866.1764
Akaike AIC	8.653138	13.54004	14.18585	12.71790
Schwarz SC	8.759707	13.64661	14.29242	12.82447
Mean dependent	452.9597	4557.918	5612.160	3204.488
S.D. dependent	104.6118	810.0221	987.7494	586.6746

Determinant resid covariance (dof adj.)	2.94E+14
Determinant resid covariance	2.53E+14
Log likelihood	-3049.348
Akaike information criterion	44.80800
Schwarz criterion	45.23427

- Appendix No.03: Graphs of the response and reaction equations



- Appendix No.04: Table of the variance components analysis.

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Variance Decomposition of AEX25:

Period	S.E.	AEX25	CAC40	PSI20	BEL20
1	17.98834	100.0000	0.000000	0.000000	0.000000
2	24.47638	98.64035	1.346231	0.000852	0.012566
3	29.08249	96.05383	3.909302	0.013546	0.023323
4	32.77966	92.73552	7.180925	0.057829	0.025730
5	35.93849	89.03660	10.78763	0.153368	0.022406
6	38.74195	85.18907	14.47554	0.315108	0.020277
7	41.29465	81.33844	18.08255	0.551651	0.027357
8	43.66275	77.57202	21.51164	0.865416	0.050922
9	45.89125	73.93972	24.70997	1.253646	0.096662
10	48.01232	70.46811	27.65372	1.709727	0.168436

Variance Decomposition of CAC40:

Period	S.E.	AEX25	CAC40	PSI20	BEL20
1	207.0947	81.63255	18.36745	0.000000	0.000000
2	271.7492	86.27014	13.60824	0.036009	0.085615
3	312.7253	89.20508	10.49039	0.075646	0.228883
4	342.7495	90.70443	8.816897	0.095947	0.382723
5	366.6525	91.08086	8.306820	0.095466	0.516852
6	386.7346	90.62522	8.672365	0.086086	0.616330
7	404.2390	89.57702	9.660049	0.085390	0.677541
8	419.9066	88.11962	11.06513	0.111259	0.703996
9	434.2166	86.38728	12.73100	0.178748	0.702967
10	447.5018	84.47586	14.54228	0.298693	0.683162

Variance Decomposition of PSI20:

Period	S.E.	AEX25	CAC40	PSI20	BEL20
1	286.0255	41.07326	11.80211	47.12463	0.000000
2	386.0509	40.21421	10.27706	49.50347	0.005255
3	452.4691	39.32312	9.135343	51.52964	0.011900
4	501.1176	38.44032	8.278816	53.26387	0.016995
5	538.4324	37.58986	7.633681	54.75677	0.019689
6	567.8436	36.78494	7.145475	56.04933	0.020260
7	591.4550	36.03179	6.774472	57.17424	0.019502
8	610.6728	35.33225	6.491875	58.15753	0.018341
9	626.4914	34.68556	6.276853	59.01997	0.017625
10	639.6419	34.08940	6.114319	59.77825	0.018023

Variance Decomposition of BEL20:

Period	S.E.	AEX25	CAC40	PSI20	BEL20
1	137.2915	75.77135	8.346174	0.032063	15.85042
2	184.2050	76.05165	5.866156	0.032783	18.04941
3	215.4087	75.65020	4.366003	0.025286	19.95851
4	238.6659	74.79902	3.598659	0.024566	21.57775
5	257.0322	73.66872	3.357578	0.048685	22.92502
6	272.0702	72.37768	3.481813	0.114583	24.02592
7	284.7018	71.00467	3.851390	0.235857	24.90808
8	295.5248	69.60040	4.379497	0.421891	25.59821
9	304.9531	68.19661	5.004654	0.677814	26.12092
10	313.2867	66.81264	5.684092	1.004912	26.49836

Cholesky Ordering: AEX25 CAC40 PSI20 BEL20