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ORIGINAL PAPER

Investigating long-term causal linkages and volatility patterns: A comparative empirical study between the developed stock markets from USA and Netherland

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Abstract:
The main aim of this research paper is to investigate long-term causal linkages and volatility patterns based on a comparative empirical study between the developed stock markets from USA and Netherland. The selected sample period covers a very long time interval, from February, 2000 to February 2023. The econometric framework includes a series of statistical tests such as Augmented Dickey Fuller (ADF) test, but also Granger causality test and VAR models. The empirical results are relevant and contribute to the existing literature regarding the behaviour of developed stock markets.

Keywords: *causality test, VAR models, volatility spillovers, developed stock market, investor, COVID-19 pandemic, extreme events.*

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1. Introduction

Considering the importance of stock market dynamics on the global economy, the main objective of this research study is to examine long-term causal connections and volatility patterns. In addition, the sample stock markets are both very important and influential, such as the stock markets from USA and Netherland.

The COVID-19 pandemic significantly affected the investment behavior and implicitly the dynamics of the stock markets. However, the global financial crisis of 2007-2008 generated much more intense turbulence regarding the behavior of stock markets, being observed very sharp decreasing trends.

FTSE Russell has launched the official report on FTSE Equity Country Classification of Markets during September 2022. Moreover, stock markets are included in certain major categories such as developed, advanced emerging, secondary emerging and frontier markets. According to this selection criterion, both stock markets for USA and Netherlands are included in the first category of developed markets.

2. Literature review

Suwannapak and Chancharat (2022) investigated the volatility patterns of stock market from Thailand in the context of COVID-19 pandemic based on GARCH-BEKK models. Lee (2020) considered it is appropriate to perceive the COVID-19 pandemic as "one of the most economically costly pandemics" from past periods of time considering the investment opportunities it can provide to strategic investors who understand the crisis behavior of the stock market.

Liu et al. (2023) investigated the linkage and correlation between the stock markets of United States and China using GJR GARCH model for the long time period starting from January 2001 to July 2021, which also covers the global financial crisis of 2008 and COVID-19 pandemic. The research study conducted by Spulbar et al. (2022) examined the volatility spillovers considering the developed stock market from Japan based on GARCH models during the selected long - time period from July 1998 to January 2022, also considering the impact of COVID-19 pandemic and other extreme events.

Birau et al. (2021) have also developed a research study in order to investigate volatility patterns focusing on selected developed stock markets from Spain and Hong Kong based on GARCH family models for the selected period from January 2015 to September 2021. In addition, Liu et al. (2020) investigated the impact of COVID-19 pandemic based on a cluster including 21 major stock market indices and revealed an interesting perspective on certain issues such as abnormal stock returns, but also on the pessimistic sentiment and uncertainty perturbation of investors.

3. Data and research methodology

This empirical study aims to examine the nexus between the S&P 500 index of USA and AEX index of Netherland. Moreover the sample period for the collected databases is starting from February, 2000 to February 2023 which includes a total number of 5786 daily observations for the selected stock market indices such as S&P 500 index and AEX index. To examine the causal relationship (Kumar et al., 2022) have used Pearson correlation and Granger causality test statistics.

To examine the causal relationship between the price and returns of two commodities, price and returns of equity and commodities, the vector auto-regression model has been used by Kumar et al. (2021b). Hence, in order to examine the causal relation here, we have applied Granger causality test and VAR models. To avoid the spurious estimations, it is advised to test the series for stationary. In this study Augmented Dickey Fuller (ADF) test has been used to test the stationarity. Several researchers (Bhat et al., 2022; Kumar et al., 2021a) have used and recommended ADF test for stationarity tests.

4. Analysis and empirical results

The price and the return series of AEX and S&P 500 index are plotted in Figure 1. The plotted graph shows mixed trend in the study period. The downward trend till 2002 is evident in both AEX and S&P 500 index series; thereafter an upward trend is visible till the end of 2007. 2008 onward a sharp decline is evident till late 2009. The major reason for such decline is the sub price crisis or 2008 financial crisis. After the crisis recovery, both the indices have shown a good rally till 2019.

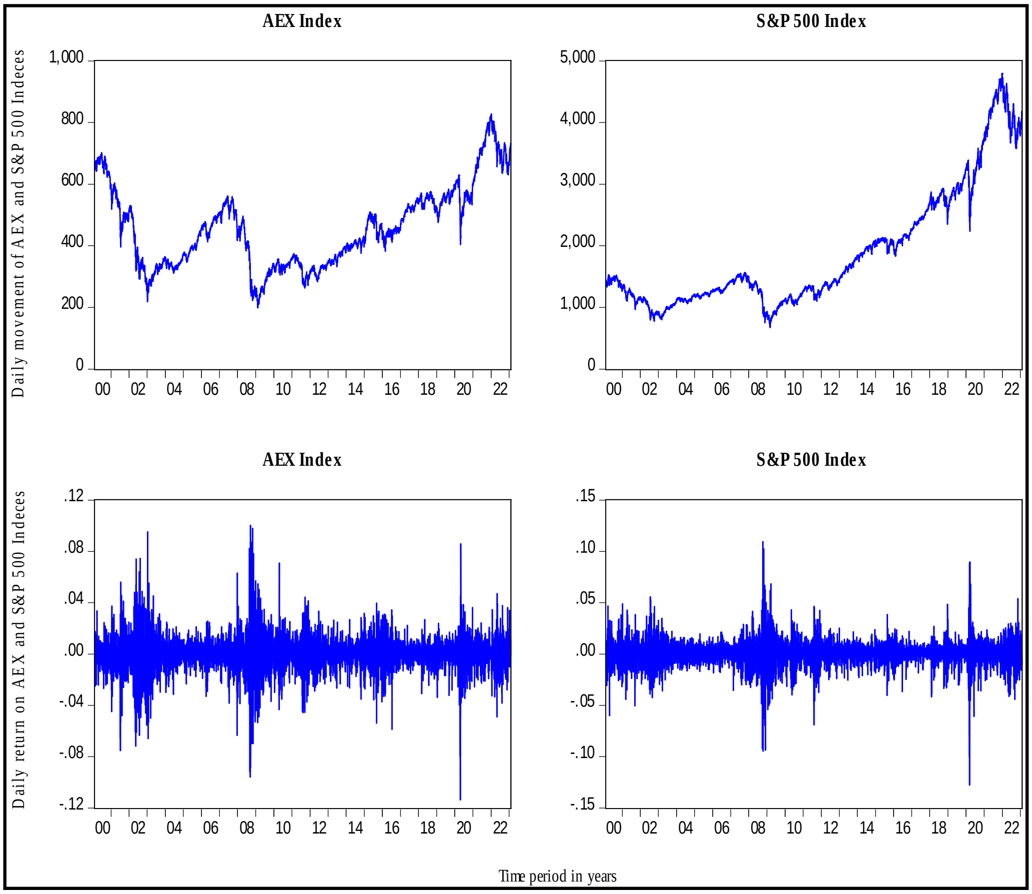

Figure 1: Price and return series of AEX and S&P 500 Index
Source: Authors processing

The minor market crash in the late 2019 or early 2020 is also evident in both the markets; the COVID 19 is the major reason for such decline. The COVID-19 pandemic recovery started from mid 2020 and the stock market went up till late 2021 and minor corrections are evident in the recent past. The line graph of AEX index resembles the S&P 500 index. This gives an initial clue of the positive relationships among AEX and S&P 500 index. Further, the presence of auto correlation is also evident from the line graph of AEX and S&P 500 indices. Moreover, a formal testing for stationarity is performed and presented in Table 2.

The descriptive statistics for the price and return series of S&P 500 index and AEX index are presented in Table 1. The mean and median for the return series of AEX index and S&P 500 index are equal 0.00 as following. However, the standard deviations of these return series are greater than 0.00. This implies that the daily returns on AEX and S&P 500 stock indices are more volatile.

A negative skewness of -0.21 and -0.37 for AEX and S&P 500 indices respectively implies the extreme losses or longer left tail in the return series. The Kurtosis value of the return series implies the presence of several fat tails in the series. The descriptive statistics confirms the presence of auto correlation in the series. The ADF test results for stationarity of the series are presented in Table 2. For the price series of AEX and S&P 500 indices, the absolute critical values at 1, 5 and 10% level are greater than the absolute t-statistics of the ADF test; the probability values are also greater than 0.05. This confirms the presence of serial correlation in the price series of AEX and S&P 500 indices. However the probability values of 0.00 for the return series of both AEX index and S&P 500 index confirmed that the series are free from serial correlation.

Table 1. Descriptive statistics for the price and return series of AEX and S&P 500 indices

Statistics	Price series		Return series	
	AEX Index	**S&P 500 Index**	**AEX Index**	**S&P 500 Index**
Mean	457.09	1884.51	0.00	0.00
Median	445.25	1433.46	0.00	0.00
Maximum	827.57	4796.56	0.10	0.10
Minimum	199.25	676.53	-0.11	-0.123
Std. Dev.	130.54	974.710	0.01	0.01
Skewness	0.55	1.24	-0.21	-0.37
Kurtosis	2.67	3.57	10.31	13.23
Jarque-Bera	318.34	1553.65	12934.39	25379.41
Probability	0.00	0.00	0.00	0.00
Observations	5786	5786	5785	5785

Source: Authors computations

Table 2. Results of test for autocorrelation

Test for autocorrelation: AEX Index							
Panel a: Price series		**t-Statistic**	**Probability**	**Panel b: Return series**		**t-Statistic**	**Probability**
ADF test statistic		-1.33	0.62	ADF test statistic		-76.49	0.00
Test critical values	1% level	-3.43		Test critical values	1% level	-3.43	
	5% level	-2.86			5% level	-2.86	
	10% level	-2.57			10% level	-2.57	
Test for autocorrelation: S&P 500 Index							
Panel a: Price series		**t-Statistic**	**Probability**	**Panel b: Return series**		**t-Statistic**	**Probability**
ADF test statistic		0.48	0.9862	ADF test statistic		-24.70	0.00
Test critical values	1% level	-3.43		Test critical values	1% level	-3.43	
	5% level	-2.86			5% level	-2.86	
	10% level	-2.57			10% level	-2.57	

Source: Authors computations

The Granger causality test results are presented in Table 3. Te probability value of 0.00 for the null hypothesis, the price series of S&P 500 index does not cause the price series of AEX index confirms that the S&P 500 cause the AEX index. The null hypotheses for the return series has been rejected at 90% level, with probability values of 0.06. These two probability values confirm that the S&P 500 index of the USA cause the AEX stock index of Netherland. Further, the bivariate VAR model has been developed to test the lead-lag relationships between the AEX index and S&P 500 index.

Table 3: Granger causality test results

Null Hypothesis	**Obs**	**F-Statistic**	**Prob.**
S&P 500 index does not Granger cause AEX index	5785	11.3125	0.00
AEX index does not Granger cause S&P 500 index		0.07486	0.93
Return on S&P 500 index does not Granger cause the return on AEX index	5784	2.80628	0.06
Return on AEX index does not Granger cause the return on S&P 500 index		1.14719	0.32

Source: Authors computations

As the price series of both AEX and S&P 500 series are not stationary, the return series of these two series were tested for serial correlation. The ADF test statistics in Table 2 confirmed that the return series of AEX and S&P 500 are stationary in their 1st differences. Hence the return series of AEX and S&P 500 are taken for the further bivariate VAR analysis.

Table 4: Lag length selection criterions

Lag	AIC	SC	HQ
0	-11.66	-11.65	-11.65
1	-11.67	-11.66*	-11.66*
2	-11.67	-11.65	-11.66
3	-11.67	-11.65	-11.66
4	-11.67	-11.65	-11.66
5	-11.67	-11.64	-11.66
6	-11.67	-11.64	-11.66
7	-11.67	-11.64	-11.66
8	-11.67*	-11.63	-11.66

Source: Authors computations

To select an appropriate lag length for this bivariate model, the Akaike Information Criterion (AIC), Schwarz information criterion (SIC) and the Hannan-Quinn information criterion (HQ) are considered. The SIC and HQ criterion recommended an appropriate lag length as 1 and AIC as 8. The information criterion statistics for AIC, SIC and HQ are presented in Table 4. As both SIC and HQ are in favour of lag length 1, we continued our analysis with VAR (1) model.

The estimates of VAR (1) bivariate model has been presented in Table5. In this univariate VAR system with lag length 1, we had 2 endogenous variables and lag length k (1). Hence, we have 2 ×1 + exogenous intercept c = 1 regressors for each equation in the system. In this bivariate VAR, there are 2 equations and a total of 6 estimates in the output. In Table 5 regression coefficients with standard error, *t*-statistics and the probability values are shown. There two significant coefficients in the VAR table at 99% level. Both of these coefficients (-0.03) of S&P 500 index with AEX index and (-0.1) of S&P 500 index with S&P 500 index are negatively significant. This implies that the previous day's index value of S&P 500 index will negatively influence the AEX and S&P 500 indices values. The negative coefficient of S&P 500 with its own previous day's value is stronger than that of negative coefficient for AEX. This implies that the initial correction in the index value happens in S&P 500 index of the USA and that correction lead to a minor correction in the AEX index on the same day. This further strengthens the evidence for significant causality relationship between AEX and S&P 500 index. The outcome of Granger causality test and the VAR (1) model are consistent to conclude that the AEX index follow the S&P 500 index or the S&P 500 index lead the AEX index.

Table 4: VAR (1) regression estimates

<table>
<tr><th>Variable</th><th colspan="2">AEX Index (-1)</th><th colspan="2">S&P 500 (-1)</th></tr>
<tr><td rowspan="3">AEX Index (-1)</td><td>-0.01</td><td rowspan="3">0.6317</td><td>0.00</td><td rowspan="3">1</td></tr>
<tr><td>-0.01</td><td>-0.01</td></tr>
<tr><td>[-0.48]</td><td>[-0.00]</td></tr>
<tr><td rowspan="3">S&P 500 Index (-1)</td><td>-0.03</td><td rowspan="3">0.0</td><td>-0.1</td><td rowspan="3">0</td></tr>
<tr><td>0.0</td><td>0.0</td></tr>
<tr><td>[-1.98]</td><td>[-8.01]</td></tr>
<tr><td rowspan="3">C</td><td>0.0</td><td rowspan="3">1.0</td><td>0.0</td><td rowspan="3">0.22</td></tr>
<tr><td>0.0</td><td>0.0</td></tr>
<tr><td>[0.14]</td><td>[1.22]</td></tr>
</table>

Source: Authors computations

5. Conclusions

This research study aimed to examine the causal relationship between the S&P 500 and AEX stock indices of the USA and Netherland respectively. The price series of these two indices were not stationary and the 1st order differenced series are stationary. The descriptive statistics concluded that the return of AEX and S&P 500 are more volatile. Further, the Granger causality tests proved that the S&P 500 index cause the AEX index value, the null hypothesis that the S&P 500 does not cause the AEX has been rejected for both price and return series at 99 and 90% levels respectively. The VAR (1) model confirmed that the yesterdays S&P 500 will negatively influence the today's value of S&P 500 index, this lead to negative influence on the value of the AEX index. This could be a good reference for day traders of S&P 500 and AEX stock indices.

Authors' Contributions:

The authors contributed equally to this work.

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