GEOGRAPHY OF STOCK MARKET CORRELATIONS

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by

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To my sister

Zeynep Kocak

ABSTRACT

It is important to understand the interactions and interdependencies between stock markets across the world, for theoretical and practical reasons such as for portfolio managers and active investors. In this thesis, we examine how the information flow around the globe interact with the non-synchronously operating stock markets in generating interdependencies between countries. Furthermore, using correlation coefficients as a measure of the co-movements among the world stock markets, we study the role of time zone differences in cross-county correlations and develop a methodology to adjust correlations to remove the impact of non-synchronous trading. As our first hypothesis, we tested the price movements of stock markets which have just closed, to see the effect of the information flow, which have already reflected by the historical prices, on the stock markets which are going to open. As our second hypothesis, correlation coefficients were cleared in terms of time differences between stock market operating hours. Our results indicated that understanding the role played by non-synchronous trading hours is import for stock market prediction studies and to understand co-movements among countries.

ÖZET

Ülke endekslerinin birbirleri ile olan ilişkilerini ve bağlılıklarını anlamak hem aktif yatırımcılar için hem de fon yöneticileri için çok büyük önem arz etmekte. Biz bu çalışmada, senkronize bir şekilde hareket etmeyen ülkelerde bilgi akışının ülkeler arasında karşılıklı bir bağlılık oluşturmasını nasıl etkilediğine baktık. Daha sonra, korelasyon katsayılarını ülkelerin birlikte yaptıkları hareketlerin birer ölçüsü olarak kabul ederek, zaman farklarının bu ilişkiler üzerlerine olan etkilerini inceledik ve korelasyonları non-senkronize hareketin etkisinden temizlemek için bir metot geliştirdik İlk hipotezimiz olarak, bilgi akışının daha açılmamış borsalar üzerlerindeki etkilerini test edebilmek, zaten bu bilgi akışını fiyatlamış olan kapanmış hisse senedi piyasalarının fiyat hareketlerini inceledik. İkinci hipotezimiz olarak ise, korelasyonları zaman farklarının etkilerinden temizledik. Bulgular gösterdi ki; Zaman farklarının dikkatli bir şekilde hizalanıp düzenlenmesi, hem fiyat hareketlerini tahmin etmek için, hem de borsaların aralarındaki ilişkinin anlaşılması için çok büyük önem arz etmektedir.

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CHAPTER I

INTRODUCTION

Active investors in financial markets spend too many working hours on predicting assets' future price movements. Understanding how prices change and what drives prices has always been a big question in financial literature. Before the opening of the stock markets, active investors tended to examine markets which had recently closed. This lead–lag effect of the stock markets got us thinking: how the prices in a stock market have an effect on others which have not opened yet.

The Efficient Market Hypothesis (EMH) suggests that prices quickly adjust all available information at any time. This adjustment of prices is almost instantaneous. The hypothesis also suggests that there is no point in trying to predict future prices by examining current or historical information. The impact of such information is already in the prices long before one may trade the asset. There is also no chance of predicting future information. This idea made us think that if trying to predict future prices is almost impossible, why do active investors work hard on it?

Let us first take two countries: Japan and Turkey. These countries' stock markets are operating in different time periods and there are no overlapping operating hours between them. Japan's stock market prices reflect all of the coming information flow immediately when the stock market is open. However, Turkey's stock markets open half an hour after Japan's stock markets close. Therefore, Turkey's stock market prices have not adjusted to such information yet. Eventually, Turkey's stock market prices should also adjust to that information. There are also many countries besides Japan and Turkey. Let us put Morocco into the scenario. As with Turkey, Morocco's stock market prices also are going to adjust to such old information. However, Morocco's stock markets open 3 hours later than Turkey's stock markets open. It means that there is also newer information to which Morocco's stock market prices are to adjust. The older information flow's power may be diminished. So, even if Turkey and Morocco are not structurally related with japan, their prices will be seen related. Then, we thought that there may be a relation between time differences and predictability power and the co-movements between countries. We have developed two tests. The first one concerns the predictive powers between stock markets. The second test concerns the co-movement between the stock markets.

We chose two major economies as base countries to test the predictive effect. One is the USA and the other one is Japan. We ran a pooled regression so as to see how cleaning the effects of time zone differences changes the predictive power of the independent countries. We saw that the leading countries' and interaction terms' betas (multiplication of independent countries and time differences) are statistically significant.

Understanding the co-movements between the countries is vital for portfolio and risk management. In this context, we tested the effect of time differences on co-movement between countries. We examined the correlation structure between the world markets in order to see the effect. Then, we sorted the correlations according to the time differences between them. While time differences increase, the correlation between countries also decreases. Then we cleaned the effects of time differences from correlations by regressing time differences on correlations. The cleared correlation's relation with the monthly return's correlations, weekly return's correlations, GDP's correlations, and bilateral trade statistics improved significantly when we changed standard correlations with the cleared ones. Cleared correlation relations with the fundamentals are much stronger than the low-frequency data's relation.

There are long debates in literature surrounding how to deal with correlation structures. Since opening and closing hours differentiate, historical daily price data of stock markets become non-synchronised. To solve this problem, researchers generally made their researches by using low-frequency (monthly, weekly) data. Working with low-frequency data has serious weaknesses. First of all, because of the time-varying features of the data, changing the observation frequency from daily to monthly or weekly makes our data biased. The second reason as to why working with low-frequency data is not efficient is that the number of observations is too small. This is why working with daily data is too important. These results, together with the prediction regressions' results, suggest that one does not need to necessarily use monthly or weekly returns.

CHAPTER II

PREVIOUS WORK

Predicting future prices by examining current or historical prices has always been an object of curiosity in financial literature. However, Eugene F. Fama (1970) suggested that if prices "fully reflect" all available information, the market is efficient. The paper examined the EMH in three different forms. The first one is the weak form (historical prices), the second is the semi-strong form (publicly available information such as stock splits or annual earnings), and the last one is the strong form (private information). The paper found strong evidence, especially pertaining to the weak and semi-strong forms. Moreover, according to the theory, there is no point in trying to predict the future prices of assets by examining current or historical information. Again, Eugene F. Fama (1998) argued that despite active investors making returns on various financial anomalies, market efficiency still exists. The paper claimed that these anomalies are making returns because active investors are overreacting or simply because they are underreacting to the coming information.

These findings of the EMH may be very significant in themselves in respect of a stock market. Still, stock market structures tend to differentiate, and geographical differences are obvious. Such differences may be reducing the efficiency of the stock markets and create gaps in the information flow while passing from country to country. Leonidas Sandoval Junior (2013) argued that to understand how stock market indices relate to each other, examining their linkages, one should study lead–lag returns in order to calculate the correlations.

Becker et al. (1990) tested the lead–lag relations between the USA and Japan stock markets.

Lin et al. (1994) again worked on the day and night returns relations between New York and Tokyo stock markets. They found that USA stock market indices day returns have significant predictive power in respect of Japan stock markets. The outcome is valid in the opposite direction, too. Furthermore, they suggested that these returns are being realised as price jumps after the markets open.

G. Mujtaba Mian and Christopher M. Adam (2000) also tested from where the returns of the Australia stock exchange are coming. They suggested that USA lagged returns have a significant effect on Australian night returns.

All three papers found significant results regarding predictive power by aligning the time mismatches between countries. These findings show that there are some kinds of lead–lag relations between the world stock markets. This may be simply because of the information flow diffusion around the clock. The lead–lag effect is used in many papers. We also tested predictability power by aligning the time mismatches.
Co-movements between the countries are also very significant in portfolio and risk management. To obtain a well-diversified portfolio, a fund manager should understand the correlation structures well.

S. Drozdz et al. (2001) argued that indices act almost as one if time differences are being aligned carefully.
However, the time differences effect should be taken into consideration because time differences and correlations have a strong linear relation. For example, G. Bonanno et al. (2000) used weekly logarithmic returns in order to solve the non-synchronous data problem.
Thomas J. Flavin et al. (2002), in Explaining Stock Market Correlation: A Gravity

Model Approach, also tried to explain the structure of correlations between the stock markets. Firstly, they conducted calculations with realised daily returns, and then carried out the same calculations with weekly returns to solve the non-synchronous data problem. However, using Close-to-Close (CtC) or low-frequency data does not solve the non-synchronous data problem.

In Peter C. Schotman and Anna Zalewska (2006), the non-synchronous trading problem is mainly explored. They argued that taking time differences into consideration improves stock market integration results. They argued that using weekly data is not logical; thus, it causes significant loss of information.

M. Martens and S.H. Poon (2001), in Returns Synchronization and Daily Correlation Dynamics between International Stock Markets, also argued that the use of CtC returns underestimates the returns correlation because international stock markets have different trading hours. Stock markets' closing and opening hours are not synchronised. Moreover, opening times are not the same as well.

CHAPTER III

DATA

Thirty-eight benchmark indices of stock exchanges were used in the paper. These include all developed markets, and some emerging, as well as some frontier markets. Data spans the period 1990–2016. However, some countries' data starts later than 1990. Fundamentals and annually constant GPD were acquired from the IMF, and bilateral trade statistics data was acquired from the World Bank. Detailed information concerned the indices and spanning periods of all countries.

Countries	Indices	Index_City	Open	Close	Greenwich	Open Start Date	Open End Date	Open NaN Percent	Close Start Date	Close End Date	Closa NaN Percent
USA	SPX Index	New York	09:30:00	16:00:00	-5	2.01.1990	23.01.2018	31%	2.01.1990	23.01.2018	31%
Canada	SPTSX Index	Toronto	09:30:00	16:00:00	-5	2.01.1990	23.01.2018	31%	2.01.1990	23.01.2018	31%
Mexico	MEXBOL Index	Mexico City	09:30:00	16:00:00	-5	19.01.1994	23.01.2018	32%	19.01.1994	23.01.2018	32%
Brazil	IBOV Index	Sao Paulo	10:00:00	17:30:00	-3	2.01.1990	23.01.2018	32%	2.01.1990	23.01.2018	32%
Chile	IGPA Index	Santiago	09:30:00	16:00:00	-4	2.01.1990	23.01.2018	32%	2.01.1990	23.01.2018	32%
Colombia	COLCAP Index	Bogota	09:30:00	16:00:00	-4	15.01.2008	23.01.2018	33%	15.07.2002	23.01.2018	33%
Peru	SPBLPGPT Index	Lima	09:00:00	16:00:00	-4	20.10.1997	23.01.2018	32%	2.01.1990	23.01.2018	32%
Argentina	BURCAP Index	Buenos Aires	11:00:00	17:00:00	-3	15.09.1995	23.01.2018	33%	30.12.1992	23.01.2018	33%
United Kingdom	UKX Index	London	08:30:00	16:30:00	0	2.01.1990	23.01.2018	31%	2.01.1990	23.01.2018	31%
Stoxxs	SX5E Index	Frankfurt	09:00:00	17:30:00	1	2.01.1990	23.01.2018	30%	2.01.1990	23.01.2018	30%
Germany	DAX Index	Frankfurt	09:00:00	17:30:00	1	2.01.1990	23.01.2018	31%	2.01.1990	23.01.2018	31%
France	CAC Index	Paris	09:00:00	17:30:00	1	2.01.1990	23.01.2018	31%	2.01.1990	23.01.2018	31%
Spain	IBEX Index	Madrid	09:00:00	17:30:00	1	2.01.1990	23.01.2018	31%	2.01.1990	23.01.2018	31%
Switzerland	SMI Index	Zurich	09:00:00	17:30:00	2	3.01.1990	23.01.2018	31%	3.01.1990	23.01.2018	31%
Sweden	OMX Index	Stockholm	09:00:00	17:30:00	2	2.01.1990	23.01.2018	31%	2.01.1990	23.01.2018	31%
Denmark	KAX Index	Copenhagen	09:00:00	17:00:00	2	15.06.2001	23.01.2018	31%	29.12.1995	23.01.2018	32%
Norway	OSEAX Index	Oslo	09:00:00	17:30:00	2	29.12.1995	23.01.2018	31%	29.12.1995	23.01.2018	31%
Poland	WIG Index	Warsaw	09:00:00	17:00:00	2	16.04.1991	23.01.2018	36%	16.04.1991	23.01.2018	36%
Hungary	BUX Index	Budapest	09:00:00	17:00:00	2	2.01.1991	23.01.2018	32%	2.01.1991	23.01.2018	32%
Russian Federation	INDEXCF Index	Moscow	10:00:00	18:45:00	3	18.05.2001	24.01.2018	32%	22.09.1997	24.01.2018	32%
Turkey	XU100 Index	Istanbul	09:30:00	17:30:00	3	9.07.1990	24.01.2018	32%	2.01.1990	24.01.2018	32%
Israel	TA-125 Index	Tel Aviv	09:45:00	16:25:00	3	18.01.1998	23.01.2018	33%	31.12.1991	23.01.2018	33%
Kenya	NSEASI Index	Nairobi	09:30:00	15:00:00	3	9.09.2011	23.01.2018	32%	25.02.2008	23.01.2018	32%
South Africa	JALSH Index	Johannesburg	09:00:00	17:00:00	2	30.06.1995	24.01.2018	32%	30.06.1995	24.01.2018	32%
Morocco	MOSENEW Index	Casablanca	09:30:00	15:30:00	0	2.01.2002	23.01.2018	32%	2.01.1995	23.01.2018	32%
Japan	NKY Index	Tokyo	09:00:00	15:00:00	9	4.01.1990	24.01.2018	33%	4.01.1990	24.01.2018	33%
Hong Kong, China	HSI Index	Hong Kong	09:30:00	16:00:00	8	2.01.1990	24.01.2018	32%	2.01.1990	24.01.2018	32%
Singapore	STI Index	Singapure	09:30:00	17:00:00	8	31.08.1999	24.01.2018	31%	31.08.1999	24.01.2018	31%
Australia	AS51 Index	Sydney	10:00:00	16:00:00	11	29.05.1992	24.01.2018	31%	29.05.1992	24.01.2018	31%
New Zealand	NZSE Index	New Zealand	10:00:00	17:00:00	12	30.03.1992	24.01.2018	31%	30.03.1992	24.01.2018	31%
Taiwan	TWSE Index	Taipei	09:00:00	13:30:00	8	3.01.1990	24.01.2018	29%	3.01.1990	24.01.2018	29%
Korea, Rep.	KRX100 Index	Seoul	09:00:00	15:30:00	9	2.01.2001	24.01.2018	32%	2.01.2001	24.01.2018	32%
Philippines	PCOMP Index	Manila	09:30:00	15:30:00	8	2.01.1990	24.01.2018	33%	2.01.1990	24.01.2018	32%
Indonesia	JCI Index	Jakarta	09:00:00	16:00:00	7	3.01.1990	24.01.2018	34%	3.01.1990	24.01.2018	33%
Indian	BSE100 Index	Mumbai	09:15:00	15:30:00	5,3	2.01.1991	24.01.2018	34%	2.01.1991	24.01.2018	34%
China	SHCOMP Index	Shenzhen	09:30:00	15:00:00	8	19.12.1990	24.01.2018	33%	19.12.1990	24.01.2018	33%
Malaysia	FBMKLCI Index	Kuala Lumpur	09:00:00	17:00:00	8	2.01.1990	24.01.2018	33%	2.01.1990	24.01.2018	33%
Thailand	SET Index	Bangkok	10:00:00	16:30:00	7	2.01.1990	24.01.2018	33%	2.01.1990	24.01.2018	33%

Table 1 Detailed information regarding the stock market indices. There are names of indices, which city they operate in, opening and closing hours, and some additional information regarding the dates, and NaN values.

CHAPTER IV

METHODOLOGY

Simple total returns were calculated and defined as follows:

Equation 1

$$Rtday = (Pt - 1close \,/\, Pt - 1open) - 1$$

where Pt – 1close is the closing price of the index on day t-1 and Pt – 1open is the opening price of the index on day t-1 for day returns.

4.1 Predictability

In this part we examined predictability to see how the information flow affects the stock markets which are not open yet. We chose the USA and Japan as the independent variables of the regressions. The USA's lagged returns were used in the regressions. Then, as dependent variables we took Asian countries and European countries. We tried to choose countries where there are no overlaps between the pairs and there are little time differences so as to make our setup more implementable. First, we made pairwise regression to see if the betas support our hypothesis or not. For US based pairwise regression results, betas are increasing while time-differences decreasing. There is some outlier pairs though but the pattern is obvious. Then we add time differences between the USA and dependent countries, and the interaction term to the regression as independent variables. Dependent variables comprised Asian countries. Results proved that time-differences have significant effect on the interactions among the countries. You may see the results at Table 3.

Regression functions are defined as follows:

Equations for US based regressions

$$\boldsymbol{\mathcal{R}_{Asian\_Countries} = \alpha + \beta_1 \mathcal{R}_{US} + \varepsilon}$$

$$\boldsymbol{\mathcal{R}_{Asian\_Countries} = \alpha + \beta_1 \mathcal{R}_{US} + \beta_2 Time\_Diff + \beta_3 \mathcal{R}_{US} * Time\_Diff + \varepsilon}$$

Equations for Japan based regressions

$$\mathcal{R}_{European\_Countries} = \alpha + \beta_1 \mathcal{R}_{Japan} + \varepsilon$$

$$\mathcal{R}_{European\_Countries} = \alpha + \beta_1 \mathcal{R}_{Japan} + \beta_2 Time\_Diff + \beta_3 \mathcal{R}_{Japan} * Time\_Diff + \varepsilon$$

where $\boldsymbol{\mathcal{R}_{Asian\_Countries}}$ are the daily return series of Asian countries, $\boldsymbol{\mathcal{R}_{US}}$ is also the daily return series of S&P500, $\boldsymbol{\beta_2 Time\_Diff}$ concerns the time differences between the pairs, and $\boldsymbol{\mathcal{R}_{US} * Time\_Diff}$ is the interaction term obtained through the multiplication of $\boldsymbol{\mathcal{R}_{US}}$ and $\boldsymbol{Time\_Diff}$.

Our second regressions were formed in the same way. Only differences are dependent variables are European countries in the regressions and independent variable is Japan. Standard errors were corrected by Newey–West test and lag(0) is specified since, there is no autocorrelation but there is heteroscedasticity.

Dependent Countries' Returns	*Time Differences (hr)*	*Betas*	*T stats*
India	6.5	-0.17	-3.69
Thailand	6	0.04	0.98
Indonesia	5	0.39	7.23
Hong Kong	4.5	-0.05	-1.13
Singapore	4.5	-0.17	-4.13
Philippine	4.5	0.35	9.54
China	4.5	-0.06	-1.18
Taiwan	4	-0.32	-9.11
Malaysia	4	0.16	3.80
Japan	3	0.44	7.30
Korean	3	-0.27	-4.61
Australia	2	0.51	15.22
New Zealand	1	0.45	16.23

Table 2 These are the results which were obtained from the first pairwise predictive regressions. According to our hypothesis, betas should increase while time-differences are decreasing. US is used as base country in here.

	Coef	T stat	P>|z|
Const	0.08	0.57	0.57
R_US	0.25	20.98	0.00
Time_Diff	-0.02	-0.63	0.53
*R_US*Time_Diff*	-0.05	-17.27	0.00

Table 3 These are the results which are obtained from pooled regression. Our aim is to see the effect of time differences. US is used as base country in here.

Dependent Countries' Returns	*Time Differences (hr)*	*Returns*	*T stats*
Morocco	3.5	0.06	2.80
England	2.5	0.39	12.26
Germany	2	0.16	4.81
France	2	0.07	2.21
Spain	2	0.07	2.10
Switzerland	1	0.08	3.05
Sweden	1	0.43	11.07
Denmark	1	0.41	8.24
Norway	1	0.46	10.01
Poland	1	-0.02	-0.79
Hungary	1	0.07	2.17
Russia	1	0.85	7.39
South Africa	1	0.40	12.19
Turkey	0.5	0.04	1.54
Isreal	0.5	0.16	3.99
Kenya	0.5	0.00	1.26

Table 4 These are the results which were obtained from the first pairwise predictive regressions. According to our hypothesis, betas should increase while time-differences are decreasing. Japan is used as base country in here.

	Coef	*T stat*	*P>|z|*
Const	0.07	0.97	0.33
R_Japan	0.12	11.59	0.00
Time_Diff	0.04	0.86	0.39
*R_Japan*Time_Diff*	-0.01	-1.88	0.06

Table 5 These are the results which are obtained from pooled regression. Our aim is to see the effect of time differences. Japan is used as base country in here.

4.2 Co-movements

4.2.1 Correlations

In this section of the paper, we studied how the information flow affects the co-movement between the countries. To test this idea, we tried to understand the correlation structures. We worked with OtC (Open to Close) returns. We first carried out the calculations with all countries' current calendar day returns. Then, we tested the relations with the USA's lagged returns. Thereafter, we chose the UK as the base country and the UK's and USA's lagged returns with the Asian continent's same day returns. Finally, we chose Japan as the base and calculated all of the correlations on the same day. By changing bases, we aimed to eliminate the idiosyncratic risks. The findings showed that correlations significantly decrease while time differences between countries are increasing. You may again see the detailed charts and graphs below. We used the Spearman rank correlation function because it captures the non-linear relationship better than does the Pearson correlation. However, the differences between the methodologies are not numerous. The findings were preserved for both. The Pearson rank correlation improved the results slightly.

Indices	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30
USA	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30
Canada	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30
Mexico	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30
Brazil	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30
Chile	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30
Colombia	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30
Peru	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30
Argentina	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30
United Kingdom	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30
Stoxxs	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30
Germany	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30
France	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30
Spain	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30
Switzerland	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30
Sweden	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30
Denmark	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30
Norway	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30
Poland	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30
Hungary	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30
Russian Federation	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30
Turkey	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30
Israel	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30
Kenya	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30
South Africa	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30
Morocco	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30
Japan	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30
Hong Kong, China	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30
Singapore	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30
Australia	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30
New Zealand	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30
Taiwan	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30
Korea, Rep.	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30
Philippines	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30
Indonesia	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30
Indian	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00
China	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30
Malaysia	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30
Thailand	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30

Indices	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00
USA	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00
Canada	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00
Mexico	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00
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Chile	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00
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Argentina	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00
United Kingdom	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00
Stoxxs	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00
Germany	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00
France	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00
Spain	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00
Switzerland	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00
Sweden	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00
Denmark	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00
Norway	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00
Poland	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00
Hungary	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00
Russian Federation	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00
Turkey	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00
Israel	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00
Kenya	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00
South Africa	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00
Morocco	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00
Japan	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00
Hong Kong, China	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
Singapore	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
Australia	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00
New Zealand	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00
Taiwan	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
Korea, Rep.	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00
Philippines	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
Indonesia	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00
Indian	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30
China	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
Malaysia	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
Thailand	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00

Table 6 Time differences visualising among world stock markets. (Base: Greenwich)

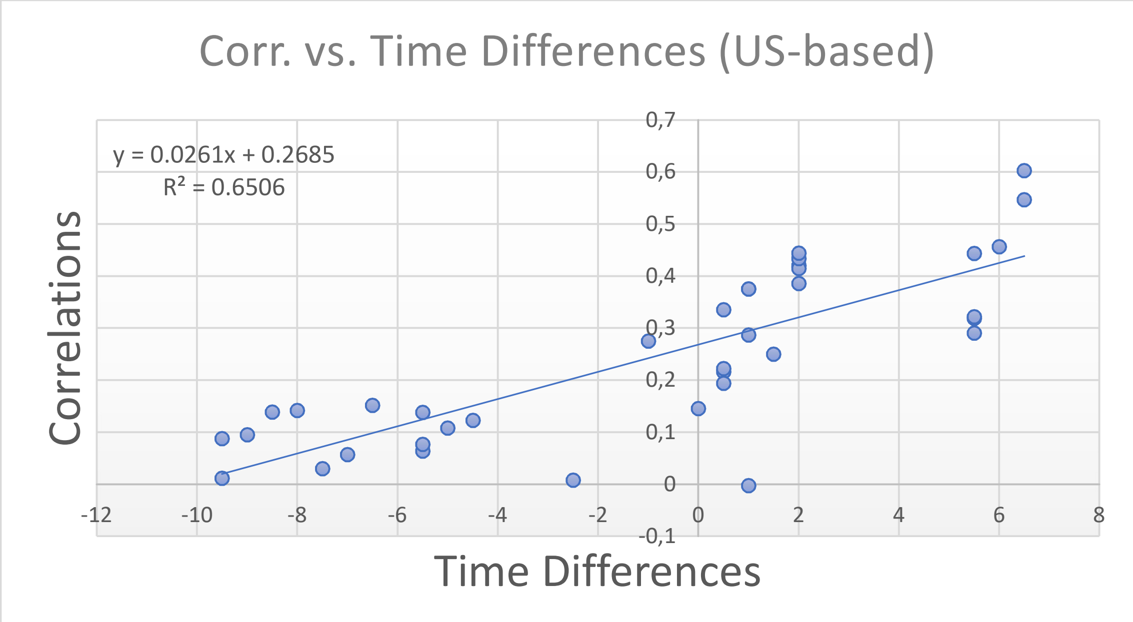

Figure 1 S&P index correlations with the other world indices. Calculations were carried out by using the same calendar day returns. Spearman correlation coefficients were used in all of the graphs instead of Pearson correlations, since there is a non-linear relationship between the historical return series.

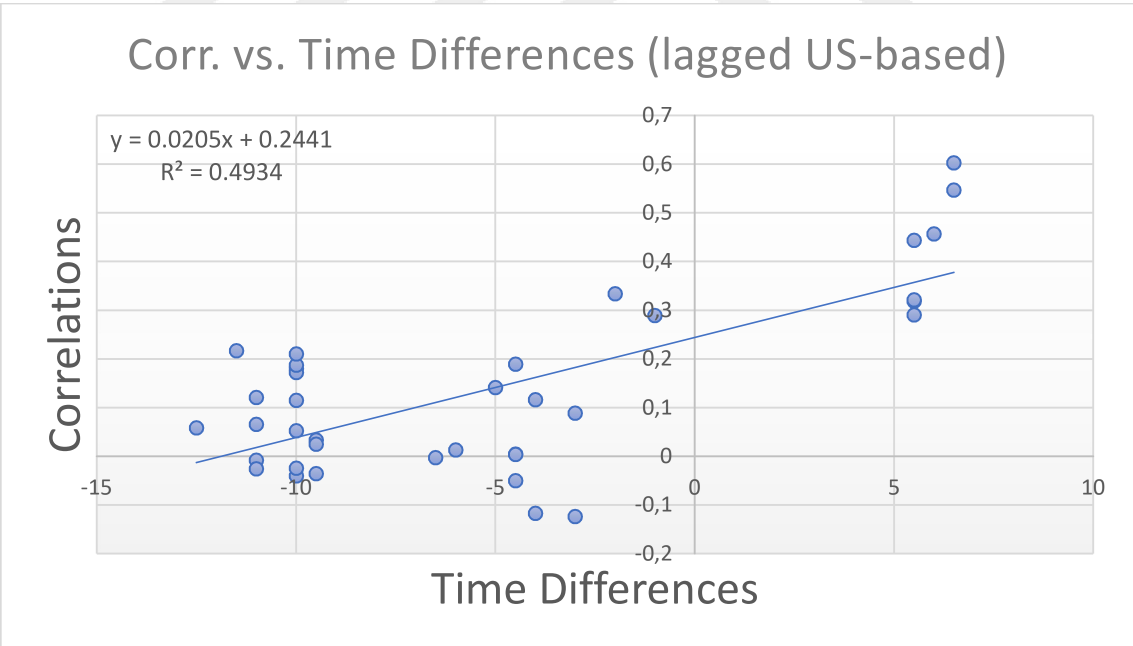

Figure 2 Lagged S&P 500 index with other's day returns.

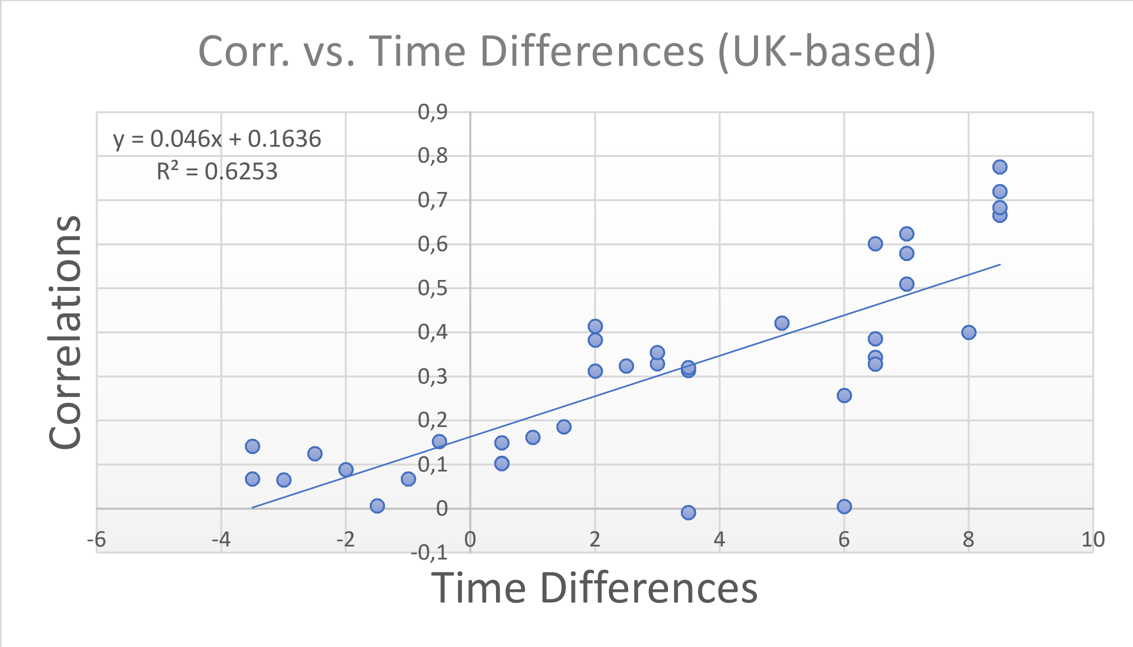

Figure 3 London Stock Exchange's correlations with the other world indices.

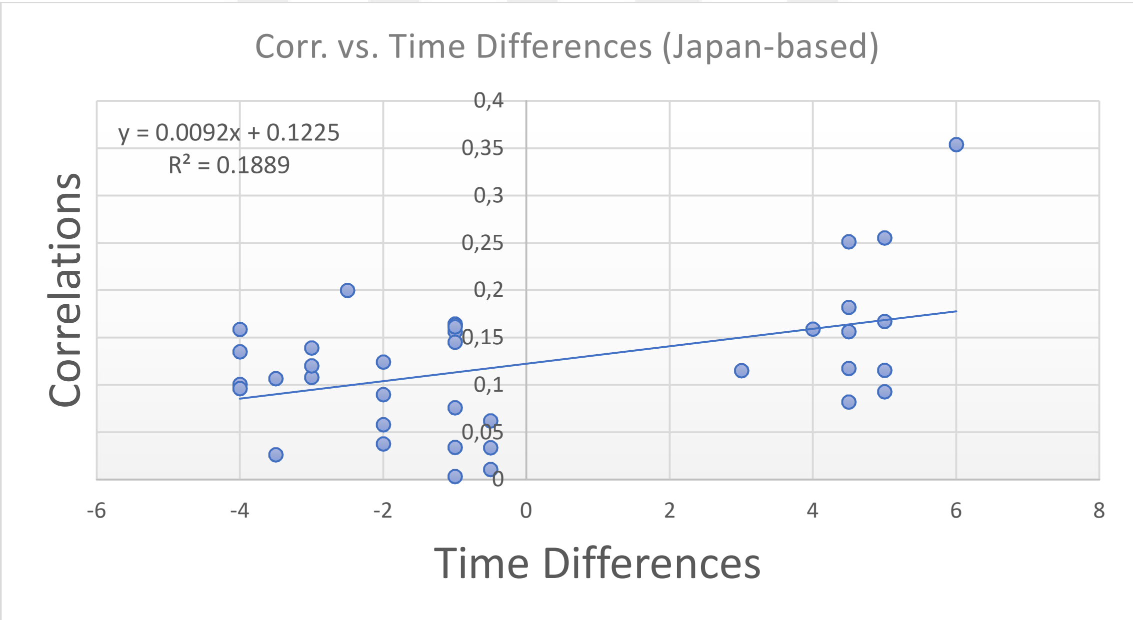

Figure 4 Nikkei 225 Stock Exchange's correlations with the other world indices.

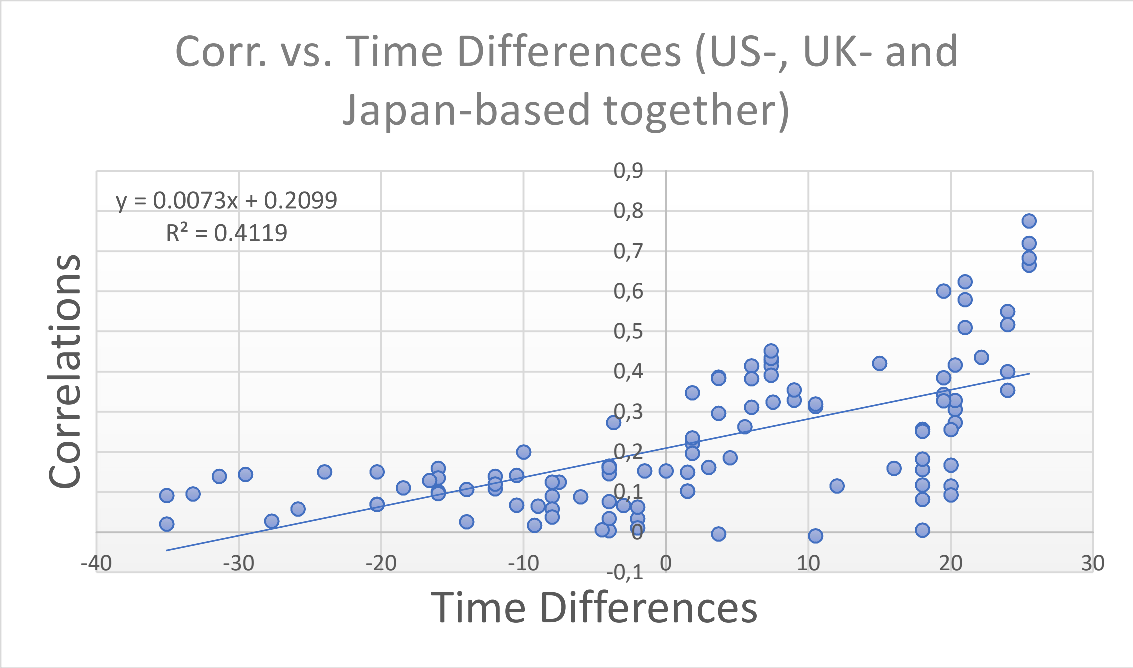

Figure 5 All day-to-day not-lagged correlations Japan-based results included.

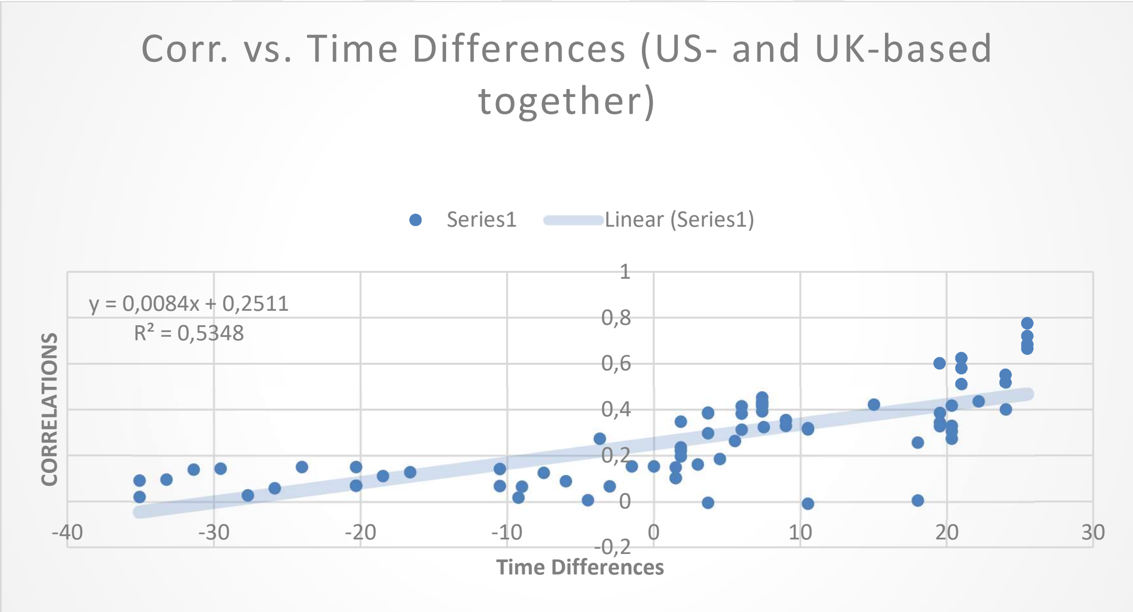

Figure 6 All day-to-day not-lagged correlations Japan-based results excluded.

4.2.2 Correlation Decomposition

After we observed that there is a significant relationship between correlations and time differences, we decided to push our tests one step forward in order to see how clearing the effect of time differences will change the correlation structure. We took correlations between S&P 500 and world stock market indices as dependent variables. Then, we took time differences between those correlation pairs as independent variables. Regression was formulated as follows:

Equation 2

$$\boldsymbol{Correlations = \alpha + \beta_1 Time\_Diff + \varepsilon}$$

Equation 3

$$\boldsymbol{Cleared\_Correlations = Correlations - (\alpha + \beta_1 Time\_Diff)}$$

The $\boldsymbol{Y_{Correlations}}$ variable concerns the correlations between S&P and the other countries and $\boldsymbol{X_{Time\_diff}}$ is concerned with the time differences between the pairs. When we left the residuals alone, we had cleared correlations. After we cleared the effect of time differences, we checked how the cleared correlations differentiate from the standard ones. We first compared both standard correlations and cleared correlations by checking their relations with weekly returns correlations. The cleared correlations relation with monthly correlations was very high. We undertook this by comparing again with the weekly returns correlation. Both results showed us that in order to solve the non-synchronous data problem, one does not need to work with low-frequency data. Adjusted correlations almost do the same thing with them.

Then we continued to compare the results. On this occasion, we calculated the relations with the countries' fundamentals. Again, we compared both correlations with the GDP data of countries. Finally, we conducted the same tests with bilateral trade statistics of the pairs. The results did not change. Adjusted correlations explain all of these variables better than do the standard correlations. You may again see the results in the graphs.

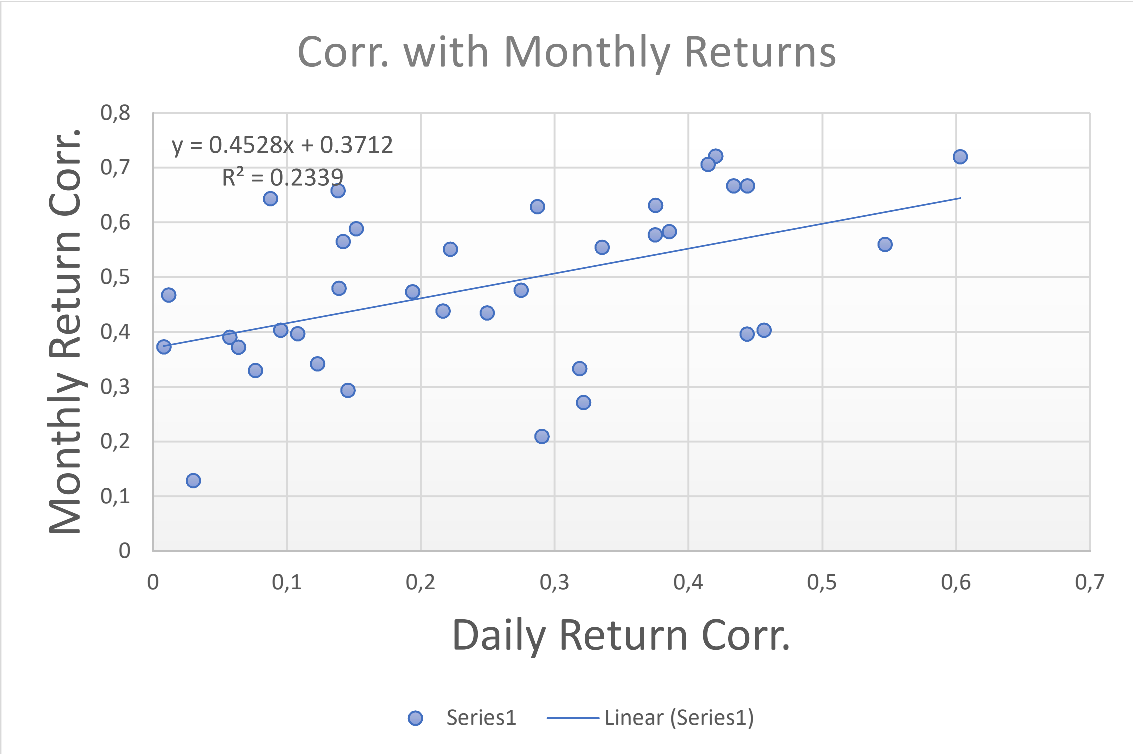

Figure 7 Standard correlation coefficients relation with monthly return's correlations.

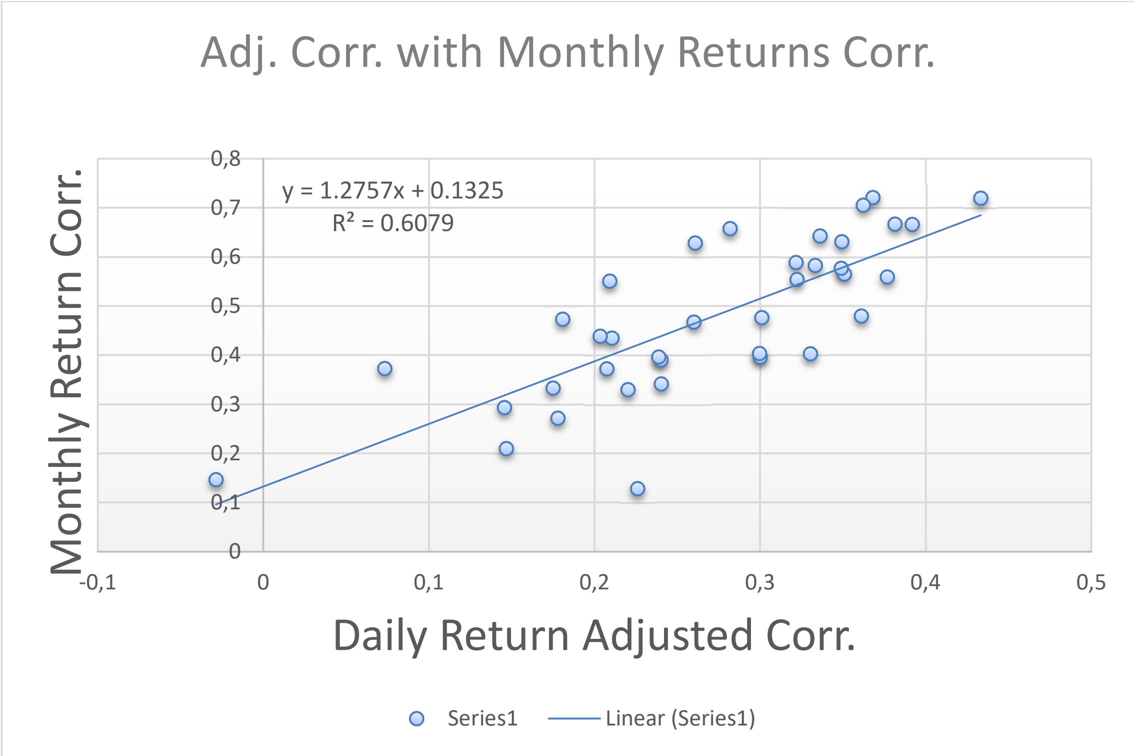

Figure 8 Cleared correlation coefficients relation with monthly return's correlations.

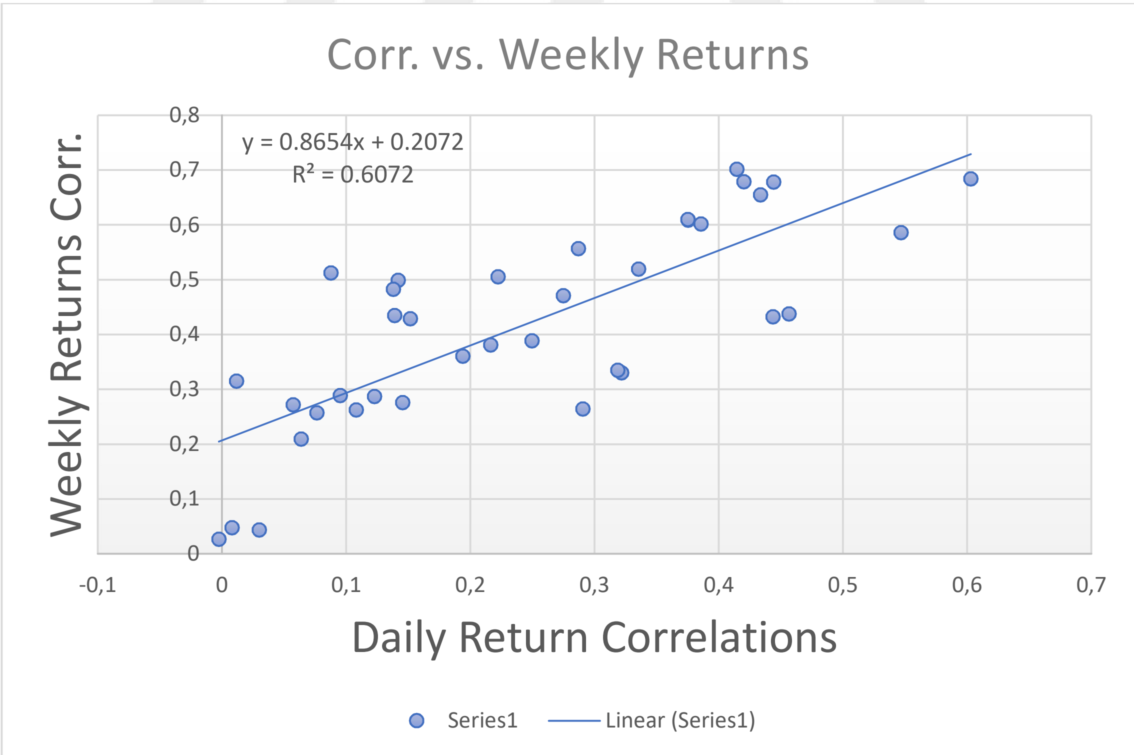

Figure 9 Standard correlation coefficients relation with weekly return's correlations.

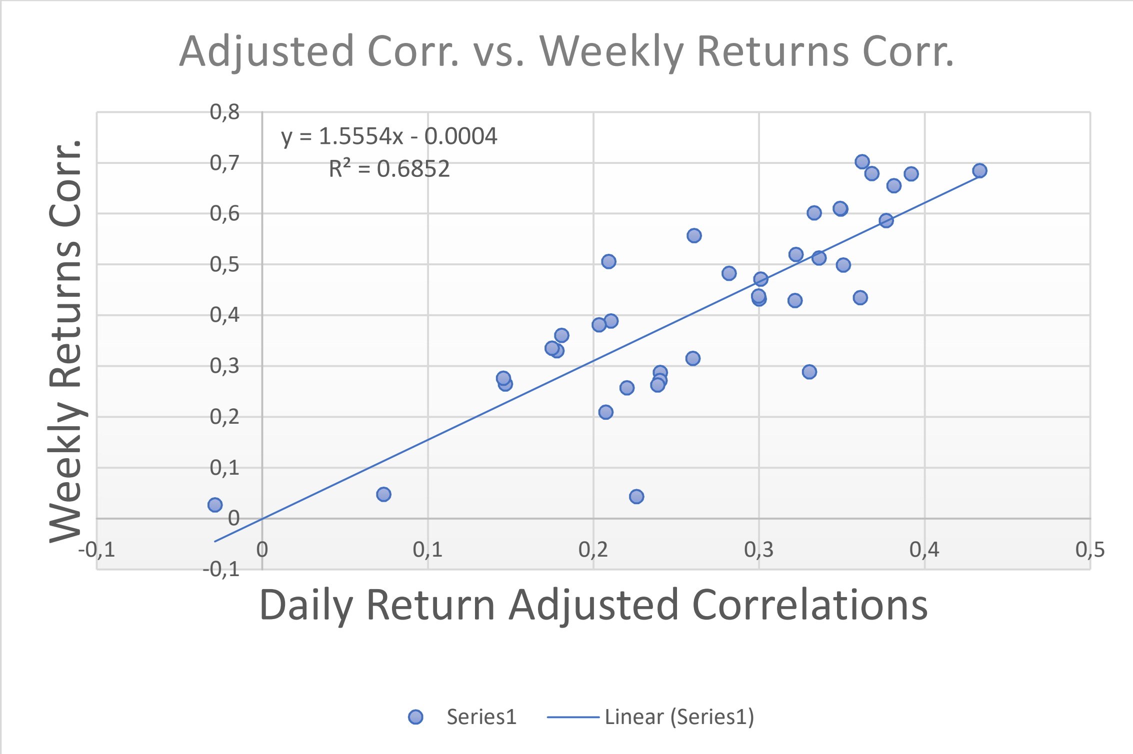

Figure 10 Cleared correlation coefficients relation with weekly return's correlations.

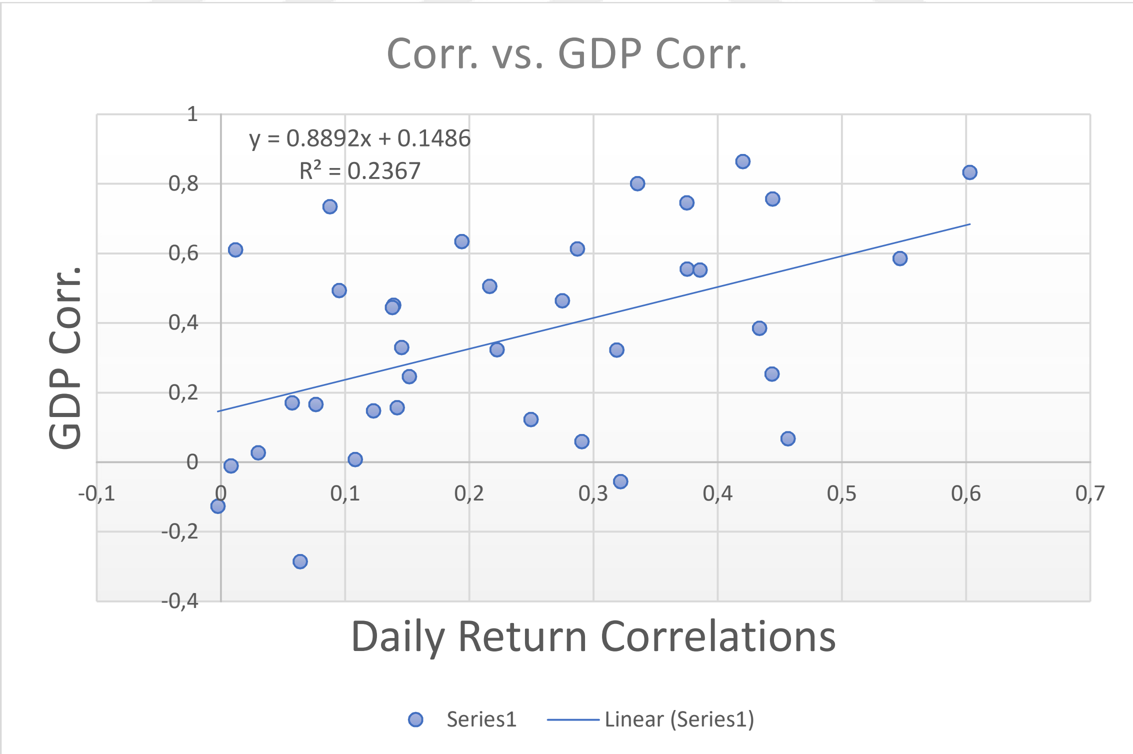

Figure 11 Standard correlation coefficients relation with GDP's correlations.

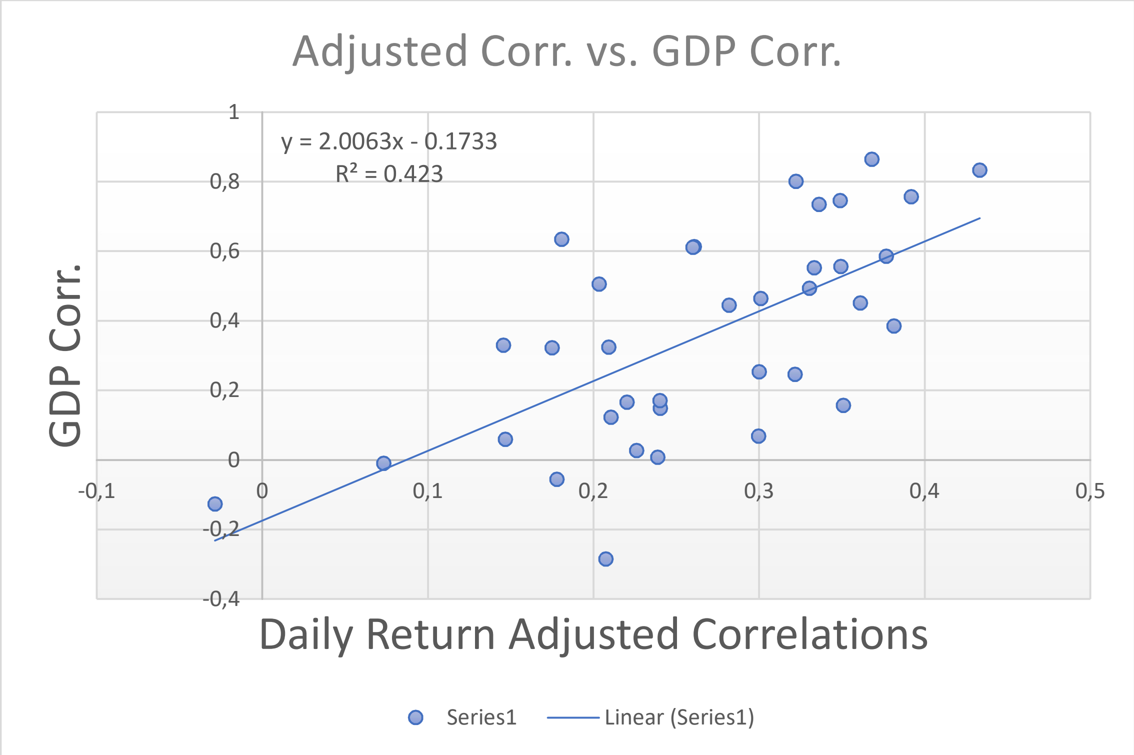

Figure 12 Cleared correlation coefficients relation with GDP's correlations.

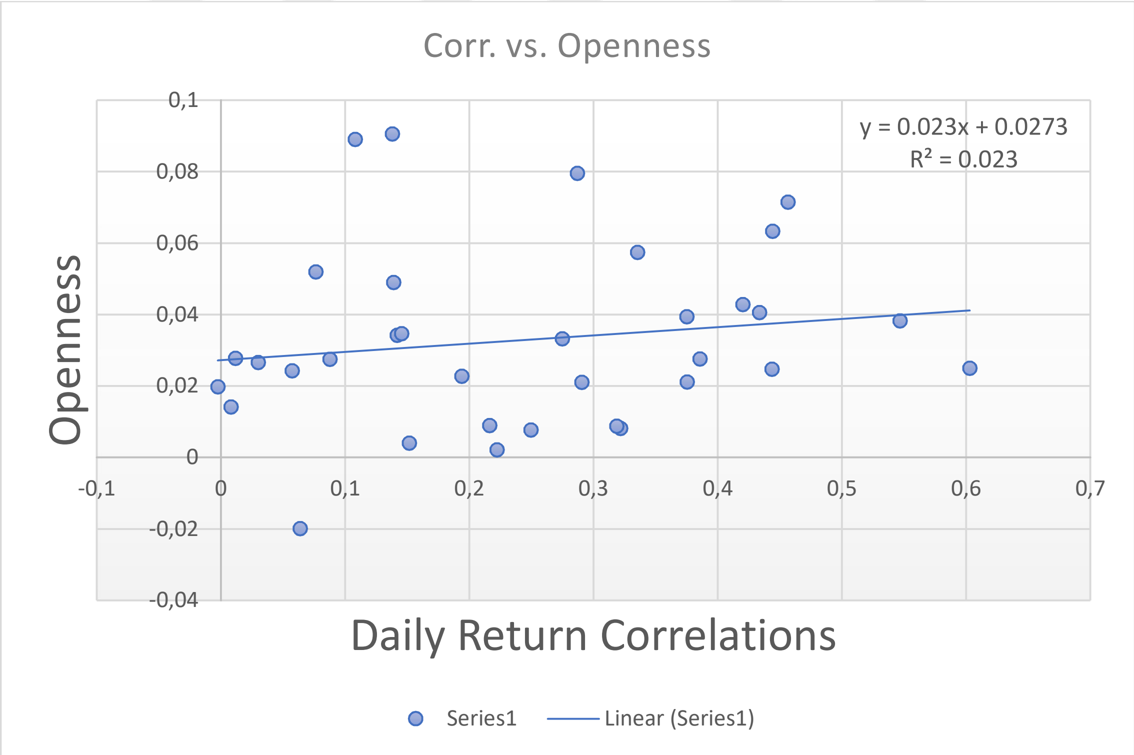

Figure 13 Standard correlation coefficients relation with bilateral trade statistics.

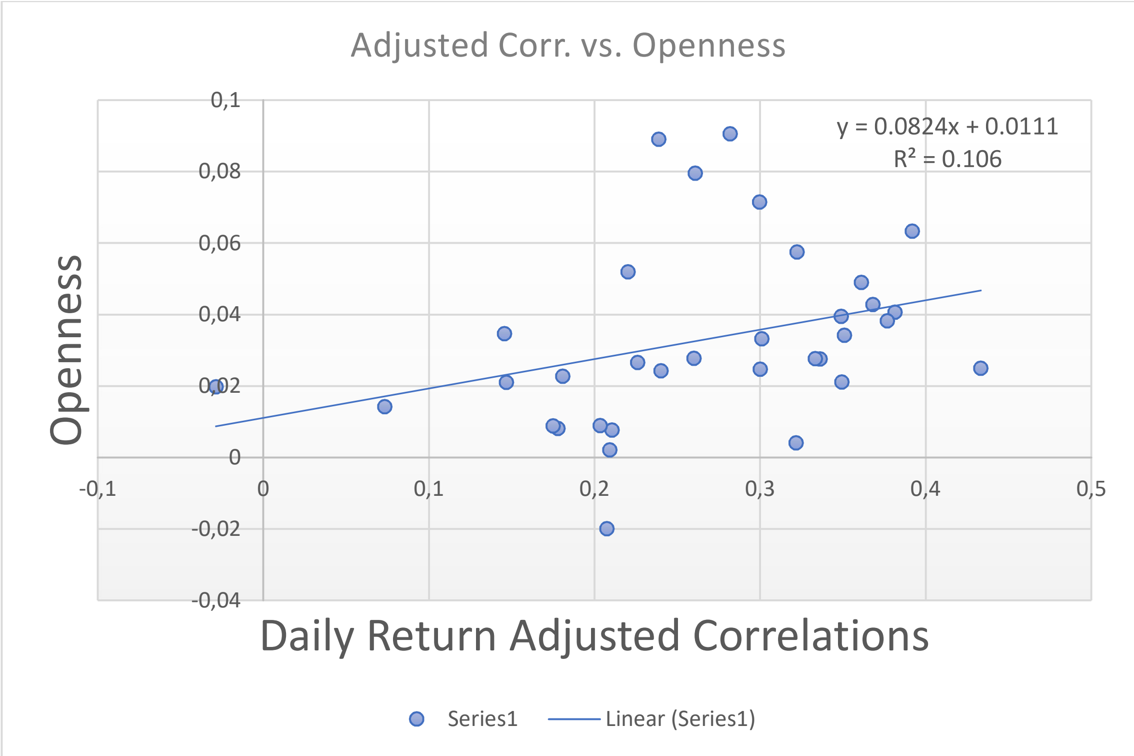

Figure 14 Cleared correlation coefficients relation with bilateral trade statistics.

CHAPTER V

ROBUSTNESS CHECK

To see if the findings are robust, we implemented several methods. First of all, our data spans approximately 30 years. Furthermore, correlations comprise time-varying historical data. Therefore, we divided the data into four subsample groups. The first period spans between 01/02/1990 and 31/12/1998, and the second subgroup spans between 01/01/1999 and 31/12/2003. The third group starts on 01/01/2004 and ends on 31/12/2011. Finally, our last period spans between 01/01/2012 and 24/01/2018. We performed a correlation clearance procedure for all of these subgroups, too. The results showed us that clearing correlations did not have much of an effect in our first subgroup. That is to say, until 2003, standard correlations and our cleared correlations did not have many differences. We may say that time differences were really important back then, since the world, trade behaviours and the information flow were not as fast and integrated. However, following the millennium era, the world became so much integrated. Information diffuses very quickly and people may react to such information simultaneously. Therefore, clearing time differences from correlations makes sense in this global, integrated world.

CHAPTER VI

CONCLUSION

Understanding how asset prices will change by examining historical or current information has always been interesting. Active investors and portfolio managers specify their investment decisions according to insights which originate from the information flow. In the paper, we tried to understand the interaction between time-differences and information flow. Furthermore, we made some tests to see how this interaction effect the dependencies between the countries. Even if the EMH suggests that in efficient markets, prices adjust to information spontaneously and simultaneously at any time, we can see that this is not the case in practical terms. Geographical reasons, especially time differences between the countries, and market structures, i.e. markets being open in different periods of time make the market structure non-synchronous. In this paper, we tried to test whether these differences between the markets in terms of time differences and market structures give us an opportunity to understand the co-movements and the dependencies among countries. In this context, we make two different implications to test our hypothesis which are prediction regressions, and correlation coefficients. To conclude, both implication's results showed that there are significant relation with time-differences and information flow. Moreover, this relation again has significant impact on the dependencies among the countries.

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