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The effect of Climatological Phenomena on Stock Markets Worldwide: Evidence for the Pacific El Niño

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Abstract: This thesis investigates the effect of El Niño on the returns of the stock indices of the USA (1950-2015), Canada, The Netherlands, Germany, UK, Norway, Japan, Korea, Peru and Indonesia (1970-2015) after controlling for several economic variables. El Niño mainly affects the returns of the Japanese Nikkei225, the Korean KSI, the Indonesian IDX Composite and the Peruvian S&P/BVL index with a magnitude of 0.81%, 1.22%, 1.37% and 3.07% for a one unit increase in the Southern Oscillation Index. Whereas an effect is found on the moment of impact (Peru), most indices are affected 6 to 9 months after the initial strike. The indices are mostly affected during the 1970-2000 period. A cross-section analysis also shows that stock returns are affected more in months that El Niño has been more severe compared to milder El Niño months.

Keywords: Stock market returns, El Niño, index, SOI, SST, time-series analysis

Contents

List of Tables & Figures

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1. Introduction

It has been long recognized that climatological phenomena have a certain effect on (economic) decision making and judgment through people’s moods and emotions (Romer, 2000). Even though the Efficient Market Hypothesis states that this should not affect prices on stock markets, earlier research has shown that this is not the case ((Saunders, 1993), (Cao & Wei, 2005), (Hirshleifer & Shumway, 2003)).

One non-seasonal climatological phenomenon that strikes cyclical and has direct and indirect consequences for countries around the globe is the El Niño-Southern Oscillation (ENSO), or simply called ‘El Niño’. The official definition of El Niño is as follows: *“A phenomenon in the equatorial Pacific Ocean characterized by a positive sea surface temperature departure from normal (for the 1971-2000 base period) in the Niño 3.4 region greater than or equal in magnitude to 0.5 degrees C (0.9 degrees Fahrenheit), averaged over five consecutive months* (NOAA, 2005)*.”* A visualization of the El Niño process is to be found in Appendix A.

The changing weather conditions due to an El Niño cycle bring along substantial climate impacts which lead to heavy draughts and bush fires in Australia, New Zealand and Indonesia for example. This in turn leads to lower agricultural output and thus changing world prices (Ornes, 2013).The Peruvian fishing industry sees its total catch declining with 50% in years of El Niño. A global effect seems logical when taking into account that Peru was responsible for over 10% of world’s total fish catch in the 1990s and still has a large share in the fishery ((Broad, Pfaff, & Glantz, 2002), (Caviedes, 1975)).

On the other hand, countries such as Canada, Argentina, Mexico and the Unites Stated gain economic growth due to the presence of an El Niño period. More rainfall in California benefits the growing of crops whereas less tornadic activity in the Midwest of the United States is also a consequences (Cashin, Mohaddes, & Raissi, 2015). Cashin et al. (2015) also find that European countries experience an increase in GDP growth due to indirect effects in the form of positive spillovers from major trading partners. They also find a significant increase in worldwide commodity prices in the aftermath of El Niño up to a period of one year after the strike.

With El Niño having effect on GDPs of countries and worldwide commodity prices, it is possible that an El Niño cycle also affects different stock markets on impact and in the period thereafter. Research regarding the effects of El Niño-Southern Oscillation cycles on stock indices of developed countries is scarce. Mainly, the effect of these cycles are tested on GDP, commodity prices and inflation level of certain countries (Brunner, 2002).

This thesis investigates the effect of El Niño on the U.S. based New York Stock Exchange (NYSE) during the period of 1950-2015, and the effect on the stock market indexes of Canada (S&P/TSX), The Netherlands (AEX), Germany (DAX), United Kingdom (FTSE All Share), Norway (MSCI Norway), Japan (NIKKEI225), Korea (KSE), Indonesia (IDX) and Peru (S&P/BVL) during a shorter period of 45 years, namely from 1970-2015[1]. The research question of the thesis is as follows:

"Does the El Niño cycle affect the returns of the different stock indices on impact or in the aftermath and in what degree?"

This research question will be the red line throughout this thesis. A clear answer to this question could be of great importance for investors, because in this way they could benefit from changing stock prices. Whereas the stock market itself is not so predictable, weather institutions in Australia and America[2] are constantly busy with predicting El Niño cycles. Investors could take advantage of this prediction by buying or selling stocks in different countries at the right time. Also, to my knowledge, there has not been any research which evaluates the effects of El Niño on U.S indices nor on European and other (in)directly affected countries with their indices. The subject of El Niño is also a contemporary subject, because the cycle strikes inter-annually and in the future it will occur even more frequently since global warming becomes more and more an issue.

To help answer the research question several hypotheses will be tested. The first hypothesis will test if El Niño has an effect on stock markets. If a significant effect is to be found, the question arises if this effect is only present at the moment that El Niño strikes or that there is also a delayed effect. The second hypothesis will test the latter. This information could be of importance for investors because a continuing effect means fewer trades for investors so less transaction costs are incurred and the net returns will be higher. To make sure that the effect which might be found actually comes from the presence of El Niño and not some confounding factors, there will be added several control variables to the regression known to have an impact on stock markets, which will be defined in the third hypothesis. The fourth hypothesis tests if the found effect is present due to a

[1] This applies if data is available. If data for a shorter period is on hands (e.g. the Dutch AEX index started in 1983), the longest time-span as possible will be used.

[2] National Atmospheric and Oceanic Administration's (NOAA) Climate Predicting center is active in giving warnings, information and predicting El Niño.

certain part of the total sample, subsamples will be used to analyze this. If the fifth and last hypothesis is rejected, it means that heavier El Niños are associated with even lower returns. This will be tested with a cross-section analysis. Since weather institutions are able to somewhat predict the magnitude of ENSO cycles, investors on the stock markets can earn higher returns by shorting the concerning indices. Another possibility is that heavier cycles are followed by more positive stock returns. Combining the results of the tested hypotheses, an answer to the research question can and will be formulated.

The main results of this research are that the El Niño cycle mainly affects the returns of the Japanese Nikkei225, the Korean KSI, the Indonesian IDX Composite and the Peruvian S&P/BVL index with a magnitude of 0.81%, 1.22%, 1.37% and 3.07% for a one unit increase in the Southern Oscillation Index (SOI). Whereas some effect is found on the moment of impact (Peru), most indices are affected 6 to 9 months after the initial strike. It is also found that the use of SOI as predictor for El Niño compared to SST is preferred and shows more statiscally significant coefficients. When breaking up the sample in different subsamples, it turns out that the returns across all the indices are mostly affected during the 1970-2000 period. the 1950-1970 and 2000-2015 period show no significance. Lastly, when looking at the difference in returns of the 15% most severe compared to the 15% mildest El Niño months, it turns out that the stock index returns are indeed affected more by El Niño when El Niño has been heavier. The European countries experience positive effects on impact and in the aftermath, whereas the South-East Asian indices are affected in a negative way. During milder months, only the Korean KSI and the American NYSE are affected.

The remainer of this paper is build up as follows: Section 2 discusses the existing literature of climatological factors affecting stock market returns and the effect of El Niño on stock markets and economies. Furthermore will the used proxies for El Niño be discussed, along with the involved countries in this research and the control variables used in the analyses. Section 3 shows the construction of the dataset and Section 4 eloborates on the used methodology. This Section also shows the hypotheses, which will be tested and answered in Section 5 Results. Output of all the analyses will be shown and discussed. Section 6 concludes the thesis with a summary of the found results, a clear answer to the stated research questions and some shortcomings concerning this research.

2. Literature review

This Section will give an insight in the broad strand of literature that concerns research on the link between El Niño Southern Oscillation, other climatological phenomena, macroeconomic factors and stock markets. Although there has not been much research on the relation between El Niño cycles and stock market prices per se, this Section will aim to introduce the different views on El Niño for predicting returns on stock indices.

2.1 Climatological factors and stock markets

In his paper, Saunders (1993) was the first to investigate the relationship between the weather and the returns on two leading indices traded on Wall Street. He found that there is a statiscally significant difference in returns on cloudy days compared to less cloudy days. This finding still holds after analyzing different stock indices and using different regression specifications. It is later confirmed in a research on twenty stock indices and shows that investors become more depressed on cloudy days, which also depresses stock returns. Snow and rain turn out to have no additional impact on stock returns (Hirshleifer & Shumway, 2003). However, Cao & Wei (2005) find a contradictory result that there is a negative correlation between the returns on stock indices and the temperature, after controlling for different existing anomalies. They state that lower temperature brings aggression to investors, which leads to more risk-taking and thus higher returns.

In the paper of Kamstra, Kramer & Levi (2003), they examined the impact of the shortness of days in fall and winter[3] on stock market returns around the world. They found an effect after controlling for other environmental factors and known anomalies. People that experience less daylight are found to be more depressed, leading to risk-aversion. This decreases stock prices and thus increasing the yields during winter periods. When spring comes in, investors lose their winter's depression leading to more risk-seeking investments. This in turn raises stock prices.

There also have been researchers which are not so keen on the impact of climatological factors on stock markets. In his paper Novy-Marx (2014) analyzes the temperature in New York on different anomaly strategies and finds that strategies concerning the size, value and long term reversal anomaly perform significantly better after cold weather. However, Novy-Marx states that the weather is not a determinant but that seasons themselves reinforce the performance of anomalies. For example the size effect, which states that stocks of small firms outperform stocks of

[3] This phenomenon is called Seasonal Affective Disorder (SAD).

large firms, is obviously present during the month January (Keim, 1983) which is considered as a cold month.

Most of the research on different weather components affecting stock prices is based on American based stock markets, but there has also been some research on Europe based stock markets. For a 1981-2000 period, Pardo & Valor (2003) find that the amount of sunshine and level of humidity play no role in explaining Spanish stock returns. In analyzing the German DAX-index, Krämer & Runde (1997) find no evidence for a weather effect. However, they do warn for the danger of data mining in this types of research. When using cloud cover or amount of precipitation as a proxy for a weather effect, it is hard to establish for example: "what is good weather?" They show that when using different criteria for good weather, the outcome of statistical tests can change rapidly. This might lead to rejecting hypotheses which should not have been rejected.

As mentioned earlier, weather effects have an impact on stock markets via people's moods. It is proven that sunshine positively affects people's moods and that more cloudy days (e.g. 'darker days') result in people being more depressed (Hirshleifer & Shumway, 2003). The non-seasonal El Niño Souther Oscillation might have an effect on stock prices in several ways. First, higher temperatures with less rainfall are measured in Australia and parts of Asia (e.g. Japan, Korea etc.) and more rainfall is found in most of North-America. This might affect the mood of investors. Countries in Europe experience no intense climatological effects, but stock prices in these countries might be affected due to positive spillovers of major trading partners which is the second possible influence of El Niño on stock markets. By destroying countries' export products or on the contrary, by generating higher production due to positive climate changes like at the east coast of America, stock markets might get distorted. This can be seen from a trend in the prices of an index.

2.2 El Niño and stock markets

As stated in the Introduction, existing literature on the El Niño subject is not abundant. There has been some research on ENSO events, but according to Brunner (2002), they are only of limited use when looking at the effect on the world economy. Adams et al. (1995) find that when ENSO cycles are forecasted efficiently, the contribution is of a magnitude of $100 million for the U.S. agricultural sector. Three years later, a similar research has been done with an outcome of an even larger magnitude. When implementing a perfect forecast on El Niño events, the estimated value on annual basis is $323 million for the agricultural sector in the United States (Solow, et al., 1998). The critique of Brunner is based on the fact that only the effect on the U.S. agricultural sector is investigated, so the results are not applicable to a broader perspective.

The statistical significance is also omitted in these earlier researches. Next to that, the use of dummy variables to designate periods of El Niño averaged more severe periods of El Niño with less strong cycles, estimating the economical and statistical effect to zero (Brunner, 2002).

In his paper, Brunner (2002) charted the relationship of world commodity prices against a proxy[4] for measuring El Niño activity and found a substantial correlation between both variables. He also found that periods of El Niño correspond with commodity price increases, whereas La Niña[5] periods are followed by real commodity price decreases. Another finding is the small positive relationship between El Niño events and the inflation rate and percentage of GDP growth. The main finding is that ENSO cycles have a statistically and economic significant effect on the world commodity prices. A one standard deviation surprise in an El Niño strike, increases commodity price inflation with approximately 3.5 percentage points[6]. ENSO cycles are also responsible for about 20% of the real commodity price movements during his 1963-1997 sample.

A point of critique on the paper of Brunner (2002) is delivered in the more recent past by Cashin, Mohaddes & Raissi (2015). They investigate the effect of El Niño shocks on real GDP growth, inflation level, energy and real non-fuel commodity prices for 33 countries dividied in 21 country-specific models. Their critique is based on the used sample of Brunner (2002). By investigating the effect of El Niño on commodity prices for the G-7 countries[7], the sample is restricted to countries which are not all directly affected by an El Niño cycle. Cashin et. al (2015) try to overcome this problem by incorporating countries in Asia, the Pacifica and the South-America. The problem of incorporating countries struck by direct impact might also arise in this research, because it most often concerns less developed countries which have inaccurate data on stock market returns and GDP numbers or simply have a 'young' stock market index[8].

The results of Cashin et. al (2015) are striking. The economic consequences are statistically significant and differ per region. Countries on the west coast of Asia and the Pacific face a shortfall in

[4] In his paper, Brunner (2002) used the Sea Surface Temperature (SST) to measure El Niño activities. An alternative often used variable is the Southern Oscillation Index (SOI). Both will be explained further in this paper.
[5] La Niña is the counterpart of El Niño. The effect of La Niña is opposite to El Niño, with water temperature dropping even further and more rain fall on the Australian coast due to intensifying low- and high-pressure systems.
[6] This effect shows economical significance over the whole period, but shows only statistical significance during the second quarter after an ENSO strike.
[7] The Group of 7 (G7) is a group consisting of Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.
[8] Peru and Singapore for example are countries which are directly affected by an El Niño cycle, but founded their stock market indexes in 1991 and 1999, respectively.

economic activity after El Niño has struck, as does Chile. This is due to the higher temperatures and periods of draughts, leading to severe bush fires (Bennetton, Cashin, Jones, & Soligo, 1998). However, the United States and the European region face growth-enhancing effects after a cycle. Another finding is that larger geographical countries and more diversified economies experience less nuisance on its GDP growth.

2.3 El Niño variables

Climatologists use three ways to measure El Niño activity. One of these measures is the use of 'trade winds', which is not a quantative measure. The other two are, which makes them useful in various analyses. The existing literature on El Niño effects makes use of the Southern Oscillation Index (SOI) and the Sea Surface Temperature (SST). An important advantage of both SOI and SST is that it concerns continuous ENSO measures, making them extremely useful in a time-series analysis. The following subsection elaborates on these two ways of measuring an ENSO cycle.

2.3.1 Sea Surface Temperature (SST)

The Sea Surface Temperature (SST) variable is obtained by taking sea surface temperature in the Pacific region between Darwin and Tahiti and comparing deviations with its historical average temperature. The SST and the below mentioned Southern Oscillation Index show a close correlation in their values (Brunner, 2002). In his paper, Brunner (2002) finds that the SST oscillates in its statistical significance on various variables when including and/or excluding those variables. Nevertheless, he is able to find significant results with the use of the Sea Surface Temperature. According to the definition of SST, an El Niño is present if the sea temperature is higher than 0.5 degrees Celsius for five consecutive months.

2.3.2 Southern Oscillation Index (SOI)

The Southern Oscillation Index (SOI) measures air pressure differentials in the so called 'Niño 3.4' region, a region between Darwin and Tahiti. When this index deviates from its historical average[9], it indicates the presence of an ENSO cycle (Cashin, Mohaddes, & Raissi, 2015). The Bureau of Meteorology from the Australian Government keeps track of the monthly SOI records. In his paper, Brunner (2002) states that when combining with economic variables, the use of SOI is

[9] The exact formula will be explained in the Methodology Section.

preferred due to a higher correlation with for example changing world commodity prices[10]. Trenberth & Hoar (1997) also advocate for the use of SOI over SST, since the Sea Surface Temperature can differ a lot over the 'Region 3.4'. Whereas on the coastal areas of this Pacific region the temperature might fluctuate between El Niño values or not, the temperature in the central Pacific might stay relatively constant. This raises the question whether there are different El Niño strikes or if it is just one long cycle.

In this research, both variables will be used in order to capture the presence and severity of ENSO cycles. A comparison can be made to decide which way of measuring is the most efficient.

2.4 Control variables

In order to test if the El Niño actually has an effect on the stock indexes worldwide and not some confounding factors, a number of economic variables which are known to have an impact on the economy of a country and on stock market prices are included in the regressions. This subsection sheds a light on the used variables.

2.4.1 Gross Domestic Product (GDP)

In existing literature, it is well known that stock markets have a positive impact on a country's long-run GDP. Since stock markets reduce the costs of mobilizing investor's savings, investments are encouraged (Greenwood & Smith, 1997). Well-functioning liquid financial systems also create transparency in information, which in the long-run positively impacts on GDP growth ((Levine & Zervos, 1998), (Beck & Levine, 2004)). In their paper, Demirguc-Kunt & Levine (1996) find that better developed stock markets are found to be more liquid. More liquid financial systems are in turn associated with higher GDP growth. However, the reverse research is scarce. Probably because GDP growth is the most important indicator of a countries' and also the worldwide economy. But from clear reasoning, we may assume that a country's GDP positively influences prices on the stock market. When GDP is increasing, the economy is up and running leading to more money in a country (e.g. higher salaries, more paid jobs, higher living standards etc.). People who have more money will increase their savings, or they will invest in the stock markets which leads to increasing prices and thus higher stock market indexes.

[10] This is tested with a Granger-causality test.

2.4.2 1-month Interest Rate

The 1-month interest rate denotes the rate at which a borrower can borrow money. The interest rate is the premium the borrower has to pay back to the lender (e.g. financial institutions/banks). The 1-month interest rate is set by banks, but can be influenced by the monetary policy from the government. If the discount rate is increased, financial institutions must borrow at a higher rate. This increase will be reflected in a higher interest rate, because money supply is lower. Earlier research has shown that changing monetary policy has a significant effect on stock price changes (Pearce & Roley, 1984). Although there has not been research specifically on the effect of changing interest rates on stock markets as a whole, Flannery & James (1984) investigated the effect of interest changes on stock returns for commercial banks. They found an inverse relation between the interest rate change and those returns. As financial institutions invest in large portions of the market's available stocks, a similar relationship can be expected for stock markets in its totallity.

2.4.3 Consumer Price Index (CPI)

A proxy for measuring the level of inflation in a country is the Consumer Price Index (CPI). There's extensive research on the effect of the inflation level on stock market prices. The main finding of these researches is that the stock market reacts negatively to unexpected inflation in the CPI ((Nelson, 1976), (Fama & Schwert, 1977), (Schwert, 1981)). However, Pearce & Roley (1984) find no evidence for a statistical relationship between the level of inflation and stock prices. An interesting result from earlier research is that in setting the level of interest rates, information of expected inflation and past inflation levels is incorporated ((Fama, 1975), (Nelson & Schwert, 1977)). This could mean that the direct effect of inflation on stock markets is absent[11], but that the effect of interest rates on the stock market is even more present.

2.4.4 Import

This variable depicts the total amount of import per month for each country. The price of import for a given country and thus the total value of import depends on exchange rates between countries. A currency appreciation for the importing country lowers import costs and affects the stock market favorably (Ma & Kao, 1990). In their paper, Grossman & Levinsohn (1989) analyse the effect of positive surprises on import prices in six U.S. industries and come to the conclusion that these positive surprises are followed by abnormal stock returns for the stocks of the concerning

[11] This would be in line with the research of Pearce & Roley (1984).

industries. From earlier literature, we should expect that lower import positively affects stock market prices.

2.4.5 Export

The research on the effect of a country's export on stock market returns is scarce, but as in Section 2.4.4, the total value of exports also depends on exchange rates. One finding in earlier research might be important for predicting the effect of monthly export on a country's stock market returns. Chakraborty, Tang & Wu (2008) find that for US industries the stock performance of exporting companies tends to move against the performance of the dollar, such that a currency appreciation seen from a dollar perspective has a negative impact on stock markets. Furthermore, an indirect effect of export on stock markets might be present since the amount of export has an positive impact on a countries' GDP (Pereira & Xu, 2000).

2.4.6 January effect dummy

The last variable incorporated in the multivariate regression is a dummy which equals 1 if it concerns the month January and 0 for the other months. This dummy depicts the January effect anomaly which states that abnormal returns can be made in the month January and this abnormal return primarily comes from small-cap firms (Thaler, 1987). There have been several possible explanations for this anomaly, one of which is the tax-loss selling hypothesis. This hypothesis states that stock prices of firms which have declined will continue to decline in the last months of the year because investors sell shares in order to realize capital gains. These prices tend to rise in the following year because there is no selling pressure on the stocks and investors want to buy back those shares (Reinganum, 1983). However the Tax Reform Act of 1986 weakens that argument, since this Act reduced the benefits of capital gains tax and the January effect stays persistent after 1986 (Haugh & Hirschey, 2006). Another possibility is the fact that institutions tend to window-dress their company numbers near the end of the year for the reporting of their numbers (Haugh & Hirschey, 2006). Nevertheless, this anomaly is a violation of the Efficient Market Hypothesis but has been persistent over time in magnitude (Moller & Zilka, 2008).

2.5 Countries

The subsection below will give a short insight on the effect of El Niño on the different countries investigated in this research.

2.5.1 United States of America

Since El Niño occurs in the Pacific Ocean, the USA experiences direct consequences of a cycle. One result is wetter-than-average conditions across the states of Texas and Florida. This heavier precipitation is a welcome factor since it benefits the agriculture sector in the form of growing crops (Ropelewski & Halper, 1987). When looking at the hurricane season, El Niño has differing effects. During a strike the Atlantic hurricane activity decreases, leading to fewer hurricanes on the west-coast of the USA. The east-coast however, experiences more hurricane activity due to changing wind directions across the Pacific Ocean (NOAA, 2012).

2.5.2 Canada

The presence of an El Niño period should lead to economic growth according to the research of Cashin et al. (2015). Periods after el Niño result in higher-than-average temperatures, mainly in the winter months. Since winters in Canada can be severe, milder winters will result in keeping the daily businesses running. This phenomenon comes from the fact that warmer waters rise among the east-coast of Canada, which also brings marine species from the South of the Pacific Sea to the coast of Canada. This favors the fishing industry. The amount of precipitation will also be lower during and after a period of El Niño (Gilham & Scott, 2016).

2.5.3 European countries

Since the occurrence of El Niño is a remote for the European countries the effect of a cycle on The Netherlands, Germany, The United Kingdom and Norway will be discussed at once. There has been little research on the climatological consequences for North-European countries, but a research that investigated the effect of El Niño on the North-Atlantic Ocean and North-European countries found that the late winters are dryer and colder, whereas South-European countries experience more precipitation ((Merkel & Latif, 2002) & (Hudson, 2014)). A positive effect on European indices might be found, since Cashin et al. (2015) find GDP growth due to positive spillovers (e.g. the fishing industry in Canada as mentioned above).

2.5.4 Japan and Korea

Since Japan is directly adjacent to the Pacific Ocean and Korea lies close to this Ocean, climatological effects arising from an El Niño cycle are logical. A first problem for both Japan and Korea is the increasing typhoon-related damage due to larger probabilities of hurricanes during a cycle. Also more rainfall in the South-east of Asia is present during the mature phase of an El Niño event, this is also known as the monsoon (Zhang & Sumi, 2002). This increasing rainfall is labeled as a positive effect by the Japanese inhabitants, because periods of drought can lead to destruction of crops that are grown in Japan (Unknown, 2006).

2.5.5 Peru

As stated in the Introduction Peru is largely affected by an El Niño cycle. The name for this phenomenon also comes from the Peruvian inhabitants. They named it El Niño because the warm coastal current usually arises during the Christmas season. The changing water streams bring along warm upwelling waters among the coast of Peru which distorts the underwater ecosystem. This distortion results in a heavy decline in the fish catch, Peru's number one export product (Broad et al., 2002). Increasing precipitation also comes along with the warm water streams. This rainfall comes in such large quantities that the drainage cannot keep up, resulting in floods at the North-Central coast of Peru (Wells, 1990). However, further landward farmers gain positive effects from the rainfall as it benefits the agricultural output (Cashin, Mohaddes, & Raissi, 2015).

2.5.6 Indonesia

The countries east of the Pacific Ocean experience a significant increase in rainfall due to El Niño, whereas countries west of the Pacific gain long periods of drought. These periods are disastrous for a country like Indonesia because, during this period most of the crops that are grown by farmers will die due to dehydration and large bushfires can arise (Jenner, 2016) . In the first instance, rain forests are intentionally set on fire by farmers to create land to grow their crops and the rainfall will extinguish the fire. During periods of El Niño however, there is almost no rainfall causing the bushfires to escalate. Because of this large parts of the Indonesian agriculture and rainforests disappear ((Siegert, Ruecker, Hinrichs, & Hoffmann, 2001) & (Fuller, Jessup, & Salim, 2004)).

3. Data

This section describes which data will be used to come to the results that can be used to test the different hypotheses and eventually answer the research question.

Monthly prices from indices of Canada (S&P/TSX), The Netherlands (AEX), Germany (DAX), United Kingdom (FTSE All Share), Norway (MSCI Norway), Japan (NIKKEI225), Korea (KSE), Indonesia (ISX) and Peru (S&P/BVL) for the period of 1970-2015[12] will be obtained from Datastream. The used indices are selected based on the location of the countries as well as the availability of data in datastream. For the NYSE index, the database of CRSP is used in order to obtain the monthly returns. As the USA are a leading index in the world economy and the fact that more data is available on this economy, this sample will include data for the period of 1950-2015. Although data for an earlier is certainly available, this thesis follows the paper of Brunner (2002). He states that data on the El Niño variable for a period prior to World War II is not directly comparable to more recent data and is often deemed unreliable. All indices are value-weighted. Table 1 shows the descriptive statistics on the different indices.

Table 1: the descriptive statistics per index based on the computed monthly returns

The skewness, kurtosis and Jarque-Bera are used for normal distribution purposes. No index seems to be normally distributed. When an index has 551 observations, this depicts a 1970-2015 period meaning that The Netherlands as well as Korea, Peru and Indonesia have an index which is founded later than 1970. The row 'Jarque-Bera' shows the probability that the indexes are normally distributed.

	USA NYSE	*Canada S&P/TSX*	*Netherlands AEX*	*Germany DAX*	*UK FTSE*	*Norway MSCI*	*Japan NIKKEI225*	*Korea KSI*	*Peru S&P/BVL*	*Indonesia IDX comp.*
Mean	0.96%	0.58%	0.78%	0.69%	0.73%	0.85%	0.54%	0.96%	2.62%	1.36%
Median	1.27%	0.79%	1.19%	0.95%	1.10%	1.02%	0.74%	0.57%	1.12%	0.69%
Maximum	16.81%	16.32%	18.97%	20.07%	52.40%	21.27%	20.14%	44.48%	69.57%	99.48%
Minimum	-21.62%	-20.99%	-29.77%	-23.43%	-27.90%	-28.77%	-24.55%	-23.16%	-30.89%	-32.67%
Std. Dev.	4.12%	4.63%	5.98%	5.72%	5.60%	7.17%	5.66%	7.38%	11.33%	9.38%
Skewness	-0.48	-0.58	-0.75	-0.47	1.10	-0.44	-0.32	0.78	1.81	3.20
Kurtosis	5.15	5.62	5.50	4.30	1.78	4.42	4.14	6.69	10.18	35.26
J-Bera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Obs	*789*	*551*	*395*	*551*	*551*	*551*	*548*	*491*	*298*	*391*
Founded	*1792*	*1950*	*1983*	*1965*	*1962*	*1970*	*1950*	*1975*	*1991*	*1983*

[12] A period of 45 years is used when the corresponding index is founded in 1970. Otherwise, the first available data point will be used.

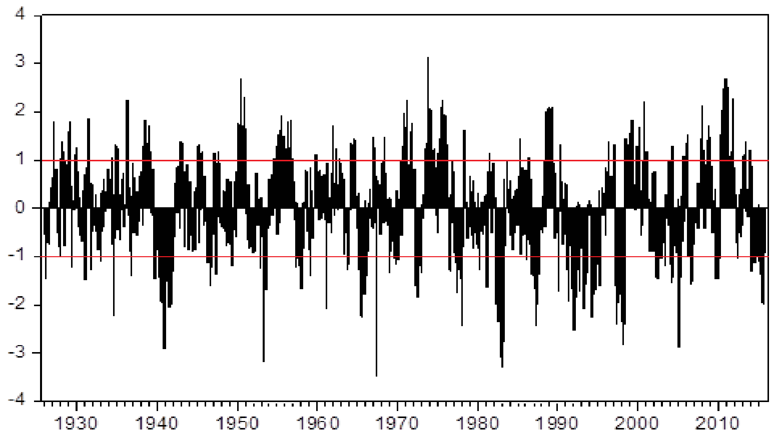
Table 1 shows that a positive average return is present over the full sample per country. Another point to mention is that for every index, except the Korean KSI, the Indonesia IDX and the Peruvian S&P/BVL, the mean return is lower than the median return. This means that the samples have more values in the left tail of the distribution, making the data left-skewed. When looking at the Jarque-Bera test scores for normality in combination with the corresponding p-values, it can be confirmed that neither of the indices is normally distributed. At last, the difference in the number of observations comes from the fact that not every index is founded at the same date.

The data on the El Niño-Southern Oscillation (ENSO) is obtained from the Bureau of Meteorology from the Australian Government. This data is called the SO(and gives an indication of the development and intensity of an El Niño or La Niña event. It uses the Mean Level Sea Pressure between Tahiti and Darwin to come to a value (Government, n.d.). The use of SOI as a proxy for El Niño is preferred when combining with economic variables (Brunner, 2002).

However, an alternative measure for determining ENSO cycles is the SST. In order for a period being labeled as an ENSO cycle, the SST has to be higher than 0.5 °C for five consecutive months[13]. Data regarding the SST is obtained from NOAA's Climate Prediction Center database. Both SOI and SST will be used in order to analyze which variable is more accurate in showing an effect on stock markets. A standardization[14] of the SOI values is used in order to narrow down the total interval. This leads to values being lower than -1 for SOI and values being higher than 0.5 for SST, indicating El Niño cycles (Cashin, Mohaddes, & Raissi, 2015). Figure 1a and 1b show the standardized SOI and SST plotted against time.

Figure 1A: The standardized Southern Oscillation Index plotted over time

The lower red line represents the boundary of an El Niño cycle. Values smaller than -1 indicate a period of El Niño striking.



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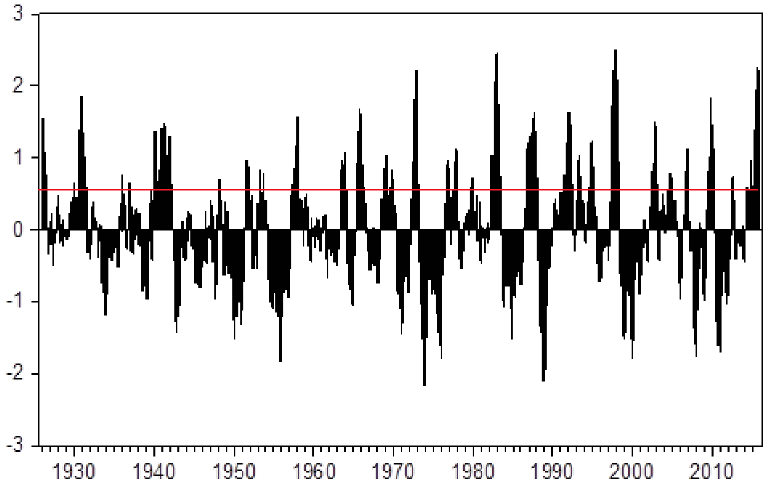
[13] Source: National Weather Service Weather forecast Office. http://www.srh.noaa.gov/tbw/?n=tampabayelninopage

[14] The SOI values are standardized by subtracting the historical mean of the monthly SOI and dividing this by the historical standard deviation.

Figure 1B: The Sea surface temperature in degrees Celsius plotted over time

The red line represents the boundary of an El Niño cycle. Values higher than 0.5 for five consecutive months indicate a period of El Niño striking.



Although it is hard to draw explicit conclusions on El Niño activity from Figure 1a and 1b,it can be seen that El Niño strikes in a cyclical manner. Also when comparing the two figures, you can see that a high SOI does not correspond with a high SST value per se. This comes from the fact that the Sea Surface Temperature varies over the ‘Region 3.4’ as earlier stated by Trenberth & Hoar (1997) and mentioned in Section 2.

To investigate whether a change in stock market returns is actually due to an El Niño cycle, control variables will be put into the regression. Data on these variables is obtained from Datastream and include the quarterly GDP, the 1-month interest rate, the monthly inflation level measured from the Consumer Price Index and the total value of monthly import and export. A first point to mention is that there are various ways to create monthly data from the quarterly GDP, such as cubic spline interpolation and linear interpolation (Mitchel et al., 2005). However, these methods require rather advanced programming. Therefore, in this thesis it is chosen to spread the quarterly data over the two adjacent months which results in monthly data. The rest of the data is not manipulated since the main interest lies in the effect of El Niño on stock markets. Another point to mention on this data is that not every variable has the full amount of observations. In some cases, the data on control variables starts later then the country’s index starts. Missing data can be substituted in three groups: data missing completely at random (MCAR), data not missing at random (MNAR) and data missing at random (MAR). In our case, the missing data is MNAR which means that there is no universal method of handling the missing data (Donders et al., 2006a). A possible and more often used method of filling missing data is mean imputation, where the mean of the sample serves as values for the missing data (Greenland & Finkle, 1995). However, a problem with this method is that mean imputation will likely bias the results (Donders et al.,2006a). This method for filling up missing data can be efficient when missing a small amount of observations (Donders et al, 2006b). But since some variables miss a sufficient amount of observations, a bias after mean imputation seems logical. Table 2 shows the descriptives. In order to get a clear view of the descriptives, all values are transformed to one currency. Appendix B elaborates on this approach. Appendix C shows the descriptive statistics of the control variables after manipulating the data.

Table 2: Descriptive statistics of control variables

Table 2 shows the descriptive statistics of the control variables per country. The GDP is presented in millions of dollars ($), the 1-month rent rate is presented in percentages, the level of inflation is presented through the countries' CPI-index and the total level of monthly import is presented in millions of dollars ($).

		USA	Canada	Netherlands	Germany	UK	Norway	Japan	Korea	Peru	Indonesia
GDP	*Mean*	$7,969,792	$954,994	$165,621	$676,081	$425,729	$67,310	$4,015,880	$140,948	$21,293	$147,750
	Median	$6,635,700	$914,602	$169,076	$676,794	$398,249	$68,198	$4,262,309	$131,664	$18,370	$147,000
	Max	$16,414,000	$1,366,492	$183,564	$785,080	$654,501	$98,058	$4,882,945	$310,592	$36,869	$173,250
	Min	$2,084,600	$586,005	$128,523	$572,511	$234,487	$36,910	$2,409,528	$21,732	$10,944	$123,000
	St.Dev.	$4,382,739	$238,855	$15,642	$63,366	$129,032	$18,739	$719,617	$90,308	$7,578	$13,800
	Obs	*789*	*417*	*237*	*297*	*549*	*453*	*429*	*488*	*295*	*69*
Rent	*Mean*	5.54%	6.33%	3.95%	4.35%	6.25%	3.75%	2.70%	2.85%	7.38%	13.00%
	Median	5.38%	5.38%	3.69%	3.94%	5.83%	2.84%	0.63%	3.06%	1.49%	8.96%
	Max	19.38%	22.06%	9.81%	14.00%	15.19%	8.49%	14.44%	5.33%	58.30%	71.00%
	Min	0.09%	0.23%	-0.15%	-0.15%	0.46%	1.10%	-0.50%	-14.40%	0.46%	3.98%
	St.Dev.	4.05%	4.33%	2.59%	2.82%	4.09%	2.15%	3.16%	2.08%	11.08%	11.53%
	Obs	*488*	*488*	*392*	*488*	*393*	*222*	*446*	*169*	*284*	*234*
CPI	*Mean*	105.2	76.9	87.3	73.1	75.5	81.4	86.9	60.4	81.2	67.6
	Median	97.9	84.7	85.4	75.2	74	89.3	99.4	60.1	84.2	69.2
	Max	238.1	127.3	117.8	107.2	100.4	140.6	104.5	110.2	120.7	121.7
	Min	23.5	20.2	62	32.1	48.4	17.5	31.9	9.9	12.6	19
	St.Dev.	71.5	32.7	17.1	21.7	13.7	37.8	20.7	30.2	25.2	29.6
	Obs	*789*	*549*	*392*	*549*	*333*	*548*	*549*	*488*	*295*	*237*
Import	*Mean*	$54,776	$20,897	$18,978	$52,270	$20,288	$2,320	$28,887	$14,045	$1,391	$5,075
	Median	$28,297	$22,531	$16,832	$48,168	$15,645	$1,842	$24,809	$8,333	$728	$2,821
	Max	$197,927	$36,015	$39,335	$91,667	$55,320	$7,795	$73,445	$45,873	$3,945	$17,417
	Min	$888	$8,181	$6,597	$22,842	$788	$217	$4,615	$473	$233	$659
	St.Dev.	$61,978	$7,884	$9,903	$20,392	$15,841	$1,686	$15,983	$13,967	$1,113	$4,802
	Obs	*729*	*333*	*392*	*297*	*549*	*548*	*549*	*488*	*295*	*388*
Export	*Mean*	$587,737	$270,332	$20,939	$66,533	$74,857	$3,546	$32,820	$14,871	$1,533	$6,252
	Median	$293,200	$282,613	$18,040	$62,908	$57,195	$2,308	$32,248	$9,350	$768	$4,546
	Max	$2,360,600	$491,278	$43,664	$114,892	$193,694	$11,047	$70,111	$51,631	$4,555	$18,648
	Min	$11,700	$72,370	$6,641	$28,895	$4,065	$142	$3,587	$287	$240	$1,021
	St. Dev.	$680,849	$135,799	$11,351	$26,412	$58,124	$3,124	$15,564	$15,191	$1,277	$4,795
	Obs	*789*	*417*	*392*	*297*	*549*	*548*	*549*	*488*	*295*	*388*

A first thing to note is the negative 1-month rent for The Netherlands, Germany, Japan and Korea. This occurred during a big economic crisis and was due to the fact that the banking sector could easily borrow from the European Central Bank at low rates. Japan introduced a negative interest rate in order to suppress the level of inflation (De Waard, 2016). Another interesting number in the descriptive statistics is the high percentage of 1-month rent on a deposit in Peru and Indonesia. When looking at the raw data, it can be seen that these percentages only hold for a short period of time during the early 90s (Peru) and the late 90s (Indonesia). When looking at the Consumer Price Index per country, there can be seen that over the whole sample, America has become more expensive. When linking the CPI to the level of inflation, this means that prices overall have inflated for America. The vice versa is true for the other countries.

4. Methodology

This section will discuss the econometric models which will be applied on the data in order to get results. The methodology of generally acknowledged benchmark papers will be used as a basis for the econometric approach in this thesis.

The below described methods will be applied to the SOI variable as well as the SST variable in order to examine which variable serves as a more accurate measure for the impact of El Niño on stock markets. Next to making a distinction between the measurement methods, the full sample will be divided into three subsamples in order to examine if the effect of El Niño on stock markets changes over time. The following division of subsample will be applied: the first period of 1950-1970 which is only applicable to the NYSE index, a second period of 1970-2000 and a last period of 2000-2015 which resembles the modern time but also has the collapse of the dot-com bubble and the big financial crisis incorporated in it. Since Figure 1A and 1B show that El Niño is less heavy and only present for short periods of time until the 1970s, we want to create a separate subsample for this period in order to check if the effect on stock markets is also less present than during the other periods. The remaining 1970-2015 period is split up at the year 2000 such that all countries can and will be analysed in both the subsamples. We have not chosen to break up this period during the 1990s because Figure 1A and 1B show that during the 90s a long and heavy El Niño has struck and the possible effect of this strike on stock markets might be reduced when cutting this cycle in two periods. Next to that, the number of observations of the latter two subsamples will lie relatively close to each other because the 1970-2000 period loses some observations due to missing control variable data.

4.1 Time-series analysis

At first, monthly returns $R_{i,t}$ will have to be computed from the prices $P_{i,t}$. This is done with the following formula:

$$R_{i,t} = \frac{P_{i,t} - P_{i,t-1}}{P_{i,t}} \quad (1)$$

The data regarding the El Niño variables (i.e. Southern Oscillation Index and Sea Surface temperature) will be standardized as mentioned in the section Data. This is in line with the study of Cashin, Mohaddes & Raissi (2015). Standardization of this data will be done as follows: the mean and standard deviation over the whole dataset will be determined, whereafter this historical mean will be substracted from each observation and this will be divided by the historical standard deviation.

The first analysis follows the methodology of Saunders (1993) and Hirshleifer & Shumway (2003) who simply estimate univariate ordinary least sqaures (OLS) regressions in order to test whether an effect of El Niño activity on stock market returns is present. Equation (2) resembles this regression:

$$R_{i,t} = \alpha_0 + \alpha_1 Niño_t + \varepsilon_t \quad (2)$$

where the dependent variable $R_{i,t}$ corresponds with the return on time t for index i and $Niño_t$ represents the value of SOI or SST at the same point in time. After running this regression, the first hypothesis is to be tested:

1. *"Both the Southern Oscillation Index (SOI) and the Sea Surface temperature (SST) have no statistical effect on the returns of stock markets."*

However, as the section Literature Review already explained, the impact of El Niño on stock market prices might not only be present on impact. To correct for this possible present effect, lagged variables of the El Niño variable will be added to the regression. This yields the following regression:

$$R_{i,t} = \alpha_0 + \alpha_1 Niño_t + \alpha_2 Niño_{t-3} + \ \ldots + \alpha_t Niño_{t-12} + \varepsilon_t \quad (3)$$

the $Niño_t$ variable will be lagged per quarter up to a period of one year. As in equation (2), the regression will be concluded with an error term. The results of this regression will help to test the second hypothesis:

2. *"The effect of El Niño on stock indices is only present on impact. There is no question of a delayed effect."*

In order to determine if there actually exists causality between El Niño activity and the returns on the different indexes and if the effect does not come from a 'disturbing' variable, several control variables will be added to the regression. These variables have been discussed in Section 2.4 and it follows the methodology of Hirshleifer & Shumway (2003) and Cao & Wei (2005).[15] When putting the control variables in the regression, equation (4) arises:

$$R_{i,t} = \alpha_0 + \alpha_1 Niño_t + \alpha_2 Niño_{t-3} + \ldots + \alpha_3 Niño_{t-12} + \alpha_4 GDP_t + \alpha_5 CPI_t + \alpha_6 r_t + \alpha_7 IMP_t + \alpha_8 EXP_t + \alpha_9 D_t^{JAN} + \varepsilon_i \quad (4)$$

next to the variables $Niño_t$, $Niño_{t-3}$, $Niño_{t-6}$, $Niño_{t-9}$ and $Niño_{t-12}$, GDP_t represents the monthly country GDP measured in own currency. r_t represents the 1-month interest rate, CPI_t gives insight in the monthly inflation level of a country and IMP_t and EXP_t depict the level of monthly import and export, respectively. Also, a dummy variable D_t^{JAN} is added which represents the January effect. Because the data is already standardized[16] a dummy variable for the different levels of an El Niño effect is not necessary. The outcomes of this regression will test if the following hypothesis is to be rejected:

3. *"The effect of El Niño on stock market returns disappears after controlling for several control variables"*

A last analysis will incorporate a lagged component of the dependent variable in the regression. Although main models in existing finance literature state that stock markets return follow a random walk (i.e. returns for the next day have no correlation with returns on the current day and are thus unpredictable), earlier research has shown that autoregressive models have shown to have significant effect. In their papers, Saunders (1993) and Cao & Wei (2005) both incorporate a one-day lagged return as an independent variable and find a significant effect on the 1-day later returns. However, it must be noted that both studies use daily returns whereas this study uses monthly returns. If the 1-month lagged return indeed has an effect on the current return and this variable is not incorporated in the regression, it means that the effect is captured by one of the other control variables which is known as the omitted variable bias. Adding the lagged return to the regression thus serves as a measure to check the reliability of the coefficients' statistical significance and gets rid of autocorrelation in a model. A possible downside of adding a lagged dependent variable is that it may bias the coefficients of the explanatory variables downwards (Keele & Kelly, 2005). Adding the lagged variable leads to the following regression:

$$R_{i,t} = \alpha_0 + \alpha_1 Niño_t + \alpha_2 Niño_{t-3} + \ldots + \alpha_3 Niño_{t-12} + \alpha_4 GDP_t + \alpha_5 CPI_t + \alpha_6 r_t + \alpha_7 IMP_t + \alpha_8 EXP_t + \alpha_9 D_t^{JAN} + \alpha_{10} R_{t-1} + \varepsilon_i \quad (5)$$

[15] The only difference is that these papers include other climatological control variables, but due to unobtainability of this data such variables will not be included in this research.
[16] This is explained in the Section 'Data'.

The above analysis will be applied to the full sample as well as the three subsamples apart. Since global warming has become more and more of an issue which in turn leads to more intense El Niño cycles, it is expected that El Niño has a larger impact on the subsample with the most recent data (Cai, 2014). The following hypothesis will be tested in order to check the validity of this statement:

4. *"the 2000-2015 subsample shows a more significant effect of El Niño on stock returns compared to the subsamples of 1950-1970 and 1970-2000."*

Next to that the SOI variable and the SST variable will be used as input for the El Niño variable and will be presented in separate tables. By following the definition of the National Weather Service Weather forecast Office of an El Niño when using SST as a proxy, the water temperature has to be higher than 0.5 °C for five consecutive months. A dummy variable that equals one if the previous four months plus the current month satisfy this criterion and zero otherwise is constructed in order to do the analysis.

4.2 Cross-section analysis

After analyzing the effect of El Niño on stock market returns through time, the potential gains from trading stocks on an El Niño based strategy can be determined using a cross-section analysis. By sorting in ascending order based on the El Niño variable SOI and dividing the SOI series in bins, the corresponding 15% of returns for the lowest (i.e. most severe El Niño periods) and highest SOI values per country can be put together to analyze the difference in impact of El Niño on both portfolios and for statistical differences between the portfolios for every country. Since the official definition of El Niño states that the standardized SOI value has to be lower than approximately -1, months that meet this criteria qualify for the cross-section analysis. This methodology follows the Cao & Wei (2005) method, who divide their sample in intervals based on the temperature and compare the returns in highest temperature interval to the returns in the lowest temperature interval. We start testing the statistical difference of mean returns between the two bins with the use of computing the following z-statistic:

$$z - score_{h,l}^{mean} = \frac{\mu_h - \mu_l}{\sqrt{\frac{\sigma_h^2}{n_h} + \frac{\sigma_l^2}{n_l}}} \qquad (6)$$

where μ_h represents the mean return for the highest bin, σ_h^2 is the variance of the return and $n_h$is the number of observations. The same applies for the lower bin.

Next to doing a z-test on the difference of means, a similar z-statistic is computed to test the difference of the frequency of positive returns:

$$z - score_{h,l}^{freq} = \frac{p_h - p_l}{\sqrt{\frac{p_h(1-p_h)}{n_h} + \frac{p_l(1-p_l)}{n_l}}} \quad (7)$$

where p_i represents the percentage of positive returns in bin *i.* This test corrects for the effect of possible outliers. Since the above z-tests only show a possible association between returns and El Niño activity, a regression will be run to find the actual correlation between the variables. This regression is explained in the section above. This cross-section anaylsis makes it possible to investigate whether the portfolio losers have experienced more or less El Niño effect. According to previous literature, some countries (e.g. European countries) should show higher returns when El Niño activity is present whereas countries as Korea and Japan experience lower returns in this scenario. The outcomes of the OLS regression from the portfolios will make it able to test the last hypothesis:

5. *"Periods of the most heavy El Niños do not affect stock market returns more than milder El Niño periods."*

The analyses throughout this thesis consist of multivariate OLS regressions. OLS regressions can have drawbacks which might affect the reliability of the output. One of these problems is the correlation between independent variables, also called multicollinearity (Dunlap & Kemery, 1987). Multicollinearity can lead to unstable paramaters and increasing standard errors which make it hard to establish the effect of those coefficients on the dependent variable. In this research, the implemented control variables are indeed correlated, see Appendix D for correlation matrices. However, the control variables show no correlation with the variables of interest (i.e. SOI and SST) which leaves these variables unaffected by collinearity (Allison, 2012). Since the incorporated economic variables serve only as control variables, there is no need to correct or delete variables. Another problem that might arise is the effect of outliers on the regression. Extreme values might pull the regression towards itself because these values have more impact on the total dataset. In this analysis, there are few outlying values when looking at Table 2. Mainly the data on the 1-month rent rate and CPI show some extreme values across the samples. Possible methods are winsorizing the outlying values or to drop them. Since it concerns control variables, the decision is made to let these values unaffected since dropping values also leads to less observations.

5. Results

In the subsections below, the results regarding the time-series and cross-section analysis will be displayed and discussed. Also the above stated hypotheses will be tested.

5.1 Time-series

5.1.1 Full sample

The first analysis contains a regression with only the El Niño variable on impact as independent variable. The results are shown in Table 3. When looking at these results, one notices that for every regression, the constant coefficient shows high significance whereas the coefficients of interest (i.e. the SOI coefficient in Panel A and the SST coefficient in Panel B) show only significance for Peru. The coefficient of -0.0208 is significant at the 1%-level. This means that a heavier El Niño cycle leads to an increase in the returns on the Peruvian index, since an El Niño is present with values lower than -1. This result is contradictory to the earlier stated literature, since El Niño decreases Peru's fish catch which is an important export product.

Another interesting point is the fact that when using the Sea Surface Temperature as independent variable, there is no significance at all. This confirms that both SOI and SST are different proxies for an El Niño cycle with different outcomes. Lastly, when looking at the R^2 of the models we find rather low values. However in this research, this is not insuperable since we are interested in the explanatory values of the coefficients. A possible explanation for these low R^2 is that there is made use of climatological variables. Since climatological variables are exposed to external factors that might have an influence. Adding the fact that the regression has few independent variables to explain the variance in the model, explains the relative low R^2 of the models.

Table 3: Univariate regression of El Niño effect on impact

Table 3 shows the results of the univariate regression per country for the full sample period. The dependent variable is the return of the index. The independent variable is in Panel A the Southern Oscillation index (SOI) and in Panel B the Sea Surface Temperature (SST). The numbers in parentheses represent the p-values of the coefficients.

A		*USA*	*Canada*	*Netherlands*	*Germany*	*UK*	*Norway*	*Japan*	*Korea*	*Peru*	*Indonesia*
SOI	*C*	0.0096***	0.0056***	0.0074**	0.0066***	0.0072***	0.0083***	0.0055**	0.0098***	0.0242***	0.0140***
		(0.0000)	(0.0046)	(0.0146)	(0.0073)	(0.0027)	(0.0072)	(0.0270)	(0.0038)	(0.0003)	(0.0036)
	SOI	-0.0014	-0.0019	-0.0017	-0.0012	-0.0014	-0.0027	-0.0014	0.0018	-0.021***	0.0052
		(0.3115)	(0.2868)	(0.5538)	(0.5927)	(0.5092)	(0.3378)	(0.5432)	(0.5680)	(0.0006)	(0.2528)
	R^2	0.0013	0.0021	0.0009	0.0005	0.0008	0.0017	0.0007	0.0007	0.0396	0.0034
B											
SST	*C*	0.0099***	0.0046**	0.0078**	0.0073***	0.0067**	0.0086**	0.0065**	0.0121***	0.0297***	0.0161***
		(0.0000)	(0.0374)	(0.0209)	(0.0067)	(0.0120)	(0.0121)	(0.0157)	(0.0011)	(0.0001)	(0.0026)
	SST	-0.0022	0.0065	-0.0011	-0.0039	0.0035	-0.0007	-0.0057	-0.0137	-0.0169	-0.013
		(0.5824)	(0.2086)	(0.8833)	(0.5377)	(0.5732)	(0.9303)	(0.3626)	(0.1129)	(0.3101)	(0.2850)
	R^2	0.0004	0.0029	0.0001	0.0007	0.0006	0.0001	0.0015	0.0051	0.0035	0.003

***, ** and * indicate significance at the 1%-, 5%- and 10%-confidence level, respectively.

With these results, it is made possible to test the first hypothesis:

1. *"Both the Southern Oscillation Index (SOI) and the Sea Surface temperature (SST) have no statistical effect on the returns of stock markets."*

There is only an effect present when the SOI is used on the Peruvian index. Overall, there is no statistical effect of the proxies for El Niño on the returns of stock markets. The first hypothesis will thus not be rejected.

It might be possible that the effect of El Niño on stock markets is not present on impact, but in the months thereafter. To test this, a multivariate regression is run where lagged SOI or SST variables are added to the regression. Table 4 shows the results of including lagged variables for SOI as well as SST.

Table 4: Multivariate regression of El Niño delayed effect and on impact

Table 4 shows the results of the multivariate regression per country for the full sample period. The dependent variable is the return of the index. The independent variables in Panel A are the Southern Oscillation index (SOI) on impact and the same variable with a lag of 3, 6, 9 and 12 months. Panel B includes the Sea Surface Temperature (SST) in the regression and has the same lagged variables as showed in Panel A. The numbers in parentheses represent the p-values of the coefficients.

A		*USA*	*Canada*	*Netherlands*	*Germany*	*UK*	*Norway*	*Japan*	*Korea*	*Peru*	*Indonesia*
SOI	C	0.0096***	0.0055***	0.0070**	0.0066***	0.0072***	0.0081***	0.0053**	0.0096***	0.0234***	0.0143***
		(0.0000)	(0.0055)	(0.0236)	(0.0074)	(0.0030)	(0.0086)	(0.0285)	(0.0044)	(0.0004)	(0.0030)
	SOI	-0.0026	-0.0014	-0.0011	-0.0020	-0.0011	-0.0038	-0.0042	-0.0014	-0.0210***	0.0030
		(0.1182)	(0.5163)	(0.7430)	(0.4540)	(0.6654)	(0.2692)	(0.1184)	(0.7135)	(0.0033)	(0.5816)
	SOI_{t-3}	0.0007	0.0006	-0.0014	0.0011	0.0003	0.0028	0.0057*	0.0075*	0.0020	0.0015
		(0.7181)	(0.8151)	(0.7193)	(0.7209)	(0.9255)	(0.4723)	(0.0580)	(0.0724)	(0.8098)	(0.8074)
	SOI_{t-6}	0.0033*	-0.0020	0.0032	0.0024	-0.0017	-0.0005	0.0012	0.0032	0.0092	0.0100*
		(0.0761)	(0.4241)	(0.3970)	(0.4310)	(0.9545)	(0.8941)	(0.6802)	(0.4486)	(0.2618)	(0.0957)
	SOI_{t-9}	-0.0019	-0.0010	-0.0042	-0.0041	-0.0027	-0.0018	-0.0053*	-0.0130***	-0.0161**	-0.0119**
		(0.3010)	(0.6914)	(0.2665)	(0.1856)	(0.3735)	(0.6473)	(0.0802)	(0.0020)	(0.0489)	(0.0484)
	SOI_{t-12}	-0.0004	-0.0009	-0.0021	0.0018	0.0007	-0.0037	0.0000	0.0025	-0.0075	0.0061
		(0.7908)	(0.6757)	(0.5328)	(0.5096)	(0.8048)	(0.2838)	(0.9898)	(0.5042)	(0.2945)	(0.2461)
	R^2	0.0067	0.0068	0.0091	0.0044	0.0029	0.0074	0.0140	0.0277	0.0687	0.0180
B											
SST	C	0.0100***	0.0042**	0.0056	0.0076**	0.0079**	0.0071	0.0046	0.0071*	0.0249***	0.0100
		(0.0000)	(0.0976)	(0.1595)	(0.0158)	(0.0102)	(0.0714)	(0.1344)	(0.0962)	(0.0053)	(0.1098)
	SST	0.0010	0.1005*	0.0021	-0.0025	0.0071	0.0013	-0.0007	-0.0119	-0.0159	-0.0139
		(0.8276)	(0.0856)	(0.8105)	(0.7313)	(0.3157)	(0.8891)	(0.9170)	(0.2245)	(0.3986)	(0.3200)
	SST_{t-3}	-0.0076	-0.0078	-0.0096	-0.0060	-0.0118	-0.0089	-0.0083	-0.0100	-0.0029	0.0040
		(0.1278)	(0.2258)	(0.3417)	(0.4533)	(0.1310)	(0.3757)	(0.2724)	(0.3639)	(0.8858)	(0.7942)
	SST_{t-6}	0.0041	0.0036	0.0141	0.0082	0.0085	0.0170	0.0016	0.0276**	0.0217	0.0215
		(0.4120)	(0.5820)	(0.1557)	(0.3012)	(0.2744)	(0.0891)	(0.8416)	(0.0121)	(0.2950)	(0.1687)
	SST_{t-9}	-0.0048	-0.0037	-0.0031	-0.0070	-0.0033	-0.0088	0.0038	-0.0032	0.0104	-0.0368**
		(0.3418)	(0.5667)	(0.7549)	(0.3816)	(0.6716)	(0.3837)	(0.6260)	(0.7749)	(0.6328)	(0.0193)
	SST_{t-12}	0.0049	0.0064	0.0070	0.0018	-0.0041	0.0069	0.0090	0.01380	-0.0020	0.0448***
		(0.2906)	(0.2723)	(0.4375)	(0.8008)	(0.5566)	(0.4477)	(0.2075)	(0.1736)	(0.9160)	(0.0015)
	R^2	0.0053	0.0080	0.0083	0.0035	0.0062	0.0063	0.0093	0.0276	0.0110	0.0340

***, ** and * indicate significance at the 1%-, 5%- and 10%-confidence level, respectively.

When comparing the results of Panel A and Panel B, one first notices that the statistically significant variables are not the same for the SOI and SST although both variables capture the activity of El Niño cycles. Also, among the different countries it turns out that SOI has a more predictive value than SST has. First, when zooming in on the European countries there is no significant effect of El Niño activity on stock market returns found. The predicted positive effect on returns due to Cashin, Mohaddes & Raissi's (2015) positive trading spillover theory is not present at all. The USA has a positive significant coefficient of 0.0033 for the 6-months lagged SOI. This means that 6 months after a strike of El Niño, the returns on the NYSE index are negatively affected by that exact strike.

The theory that countries that lie closer to the Pacific Ocean will be affected more by El Niño can be confirmed when looking at the results. Japan, Korea, Peru and Indonesia's stock exchanges are all affected at a certain point in time after an El Niño cycle. A remarkable finding is that for both Japan as Korea 3 months and 9 months after an El Niño the returns on the Nikkei 225 index and the KSI index are affected. After 3 months both the Japanese as the Korean indices are negatively affected by El Niño (with the magnitude of 0.57% and 0.75% for every unit decrease[17] in SOI value on a monthly basis), whereas after nine months both are positively affected, Japan with a coefficient of -0.0053 and Korea with a coefficient of -0.0130. A possible explanation for this pattern might come from the damage-increasing typhoons which leads to a decrease of stock market returns and the heavy rainfall which benefits the agricultural sector on the longer term, leading to higher returns on the longer term.

Peru and Indonesia also experience a positive effect on their stock market returns 9 months after a cycle of El Niño. Next to that, Peru also has a highly significant negative coefficient on the moment that El Niño strikes. When looking at the economical significance of these coefficients, it is found that a heavier El Niño is associated with a relatively large increase in the returns on the S&P/BVL (Peru) and the IDX composite (Indonesia). On the moment of impact, the coefficient has stayed approximately the same for the Peruvian index with a 2.1% increase on a monthly basis for a one unit decrease in SOI value. Also incorporating the 1.61% increase after 9 months (Peru) and the 1.19% increase after 9 months (Indonesia), results in a significant effect on the Peruvian and Indonesian stock market. This effect however, is contradictory to the stated literature where the effects of El Niño on the different countries are discussed. As Cashin et al. (2015) found that the Indonesian GDP faces a shortfall up till the second quarter after an El Niño and that is has the highest inflation jumps. They find no significant effect on Peruvian GDP an give as explanation that the benefits of the agricultural output offsets the disadvantage of the lower export in fishery. Perhaps that incorporating the control variables in our regression gives a more explanatory outcome when looking at SOI coefficients.

Looking at Panel B, there can be seen that using the Sea Surface Temperature as a proxy for an El Niño gives less significant results. Again, the European countries show no effect at all and the most prominent effects are to be found at the South-East Asian countries. Korea shows a 2.76% increase 6 months after an El Niño in stock market returns. Indonesia shows a decrease on the IDX

[17] Because the SOI concerns negative values, I discuss a 'decrease' in SOI value. In fact, this implies a more severe/heavier El Niño cycle.

composite 9 months after a strike, but the returns are pulled up by a highly significant SST_{t-12} coefficient (0.0448). A last remarkable result is the coefficient which is found with the Canadian sample. The SST variable shows a significant coefficient of 0.1005. This means that a heavier El Niño in terms of Sea Surface Temperature is associated with 10.05% increase on the S&P/TSX on a monthly basis. An explanation for this high coefficient can be constructed with the help of Figure 1.1b. Here can be seen that the SST variable shows not much variability such that the temperature will not rise with for example 1.5 °C on a monthly basis. There must be also noted that this coefficient is significant at the 10%-confidence level. Furthermore the R^2 of every model shows an increase when compared with the regressions of Table 3. More independent variables bring in more occasion to explain the variance of the models.

Lastly, when looking at the economic significance of the coefficients we see that almost all the coefficients of Canada and the European countries have the correct sign mainly when zooming in on Panel A. A negative coefficient indicates a positive effect on stock market returns. This is in line with the positive spillover theory of Cashin et al. (2015). The magnitude of El Niño on European stock market return is not enormous (i.e. about an average of 0.2% for a one unit increase in either SOI or SST).

Combining the results of Table 4 with the earlier written literature and researches as discussed above, it is possible to test the second hypothesis which is stated as follows:

2. *"The effect of El Niño on stock indices is only present on impact. There is no question of a delayed effect."*

As found earlier, the effect of El Niño is certainly not present on impact for every stock index. But taking into account the results of Table 4, we find delayed significant effects across the samples. The above stated hypothesis is not applicable on every country, but certainly the South-East Asian countries and Peru show significant delayed effects of El Niño on stock market returns. The hypothesis will thus be rejected.

As stated earlier, it might be possible that the found effects in Table 4 are not due to the effect of El Niño actually but come from some unobserved factors. The following analysis consists of a multivariate regression where several control variables are added to the regression. These variables are explained in Section 2.4. Table 5 below presents the results of the regression with the SOI variable incorporated in it whereas Table E1 in Appendix E shows the results when using Sea Surface Temperature as independent El Niño variable. Tables regarding the SST anomaly are displayed in Appendix E due to brevity.

Table 5: Multivariate regression with SOI after adding control variables

Table 5 shows the results of the multivariate regression per country for the full sample period. The dependent variable is the return of the index as stated in Regression 3. The independent variables are the Southern Oscillation index (SOI) on impact and the same variable with a lag of 3, 6, 9 and 12 months. GDP represents the monthly GDP in millions for each country in its own currency, R is the 1-month interest rate, CPI is a monthly index number, import and export are depicted monthly in millions[18] and D_{jan} is a dummy variable that equals 1 in the month January and 0 otherwise. The numbers in parentheses represent the p-values of the coefficients.

	USA	*Canada*	*Netherlands*	*Germany*	*UK*	*Norway*	*Japan*	*Korea*	*Peru*	*Indonesia*
C	0.0159	0.0339	0.2609**	0.7349***	0.1192*	0.0715	0.2752***	0.0165	-0.1007	0.0131
	(0.4742)	(0.5032)	(0.0204)	(0.0095)	(0.0929)	(0.5986)	(0.0079)	(0.1826)	(0.2653)	(0.6108)
SOI	-0.0028	-0.0020	-0.0030	0.0017	-0.0022	0.0013	-0.0036	-0.0009	-0.0173**	-0.0021
	(0.1980)	(0.4408)	(0.5131)	(0.6686)	(0.4206)	(0.7993)	(0.2603)	(0.7996)	(0.0136)	(0.7282)
SOI_{t-3}	-0.0005	0.0035	-0.0016	-0.0018	0.0029	0.0055	0.0033	0.0081*	0.0027	0.0030
	(0.8370)	(0.2431)	(0.7459)	(0.6942)	(0.3481)	(0.3254)	(0.3512)	(0.0530)	(0.7265)	(0.6617)
SOI_{t-6}	0.0051	0.0020	0.0027	0.0035	-0.0001	0.0039	0.0042	0.0040	0.0128	0.0087
	(0.0346)	(0.5059)	(0.5747)	(0.4300)	(0.9750)	(0.4819)	(0.2462)	(0.3396)	(0.1004)	(0.2123)
SOI_{t-9}	-0.0036	-0.0010	-0.0052	-0.0062	-0.0022	-0.0006	-0.0081**	-0.0122***	-0.0134*	-0.0137**
	(0.1336)	(0.7317)	(0.2839)	(0.1612)	(0.4449)	(0.3254)	(0.0250)	(0.0038)	(0.0822)	(0.0479)
SOI_{t-12}	0.0007	-0.0038	-0.0020	0.0022	-0.0016	-0.0027	-0.0009	0.0029	-0.0064	0.0008
	(0.7579)	(0.1570)	(0.6520)	(0.5764)	(0.5418)	(0.5835)	(0.7881)	(0.4310)	(0.3610)	(0.8999)
GDP	7.60E-10	1.10E-07	1.10E-06	-1.10E-06	-1.20E-07	3.50E-07	9.20E-11	6.88E-11	1.20E-06	
	(0.8851)	(0.1374)	(0.3429)	(0.0372)	(0.3883)	(0.3609)	(0.5938)	(0.8261)	(0.5136)	
R	-0.0005	-0.0042***	-0.0196***	-0.0094***	-0.0020	-0.1226***	-0.0048***		0.0034**	-0.0009
	(0.4989)	(0.0079)	(0.0011)	(0.0073)	(0.1548)	(0.0001)	(0.0116)		(0.0447)	(0.1244)
CPI	-3.90E-05	-0.0008	-0.0046*	-0.0020	-0.0013	-0.0015	-0.0029*	-0.0002	0.0006	0.0001
	(0.8919)	(0.4542)	(0.0988)	(0.4159)	(0.2679)	(0.3602)	(0.0650)	(0.8492)	(0.7270)	(0.7780)
IMPORT	-4.00E-07	-3.10E-06	-0.0041	-7.40E-07	-2.50E-60	-1.90E-06	-2.80E-06	-7E-06***	-9E-05***	-7.37E-06
	(0.1742)	(0.1157)	(0.5372)	(0.5803)	(0.4966)	(0.1046)	(0.6223)	(0.0035)	(0.0012)	(0.1319)
EXPORT	2.80E-08	2.30E-08	-3.10E-06	3.2E-06*	1.20E-06	-4.70E-07	-6.80E-09	6E-06***	5.9E-05***	6.07E-06
	(0.2138)	(0.8206)	(0.6462)	(0.0643)	(0.3128)	(0.5510)	(0.3330)	(0.0091)	(0.0014)	(0.3322)
D_{jan}	0.0006	0.0165*	0.0260*	0.0122	0.0197**	0.0208	0.0034	0.0112	0.0435*	0.0275
	(0.9348)	(0.0565)	(0.0648)	(0.3401)	(0.0239)	(0.2140)	(0.7675)	(0.3660)	(0.0585)	(0.1689)
R2	0.0280	0.0620	0.1054	0.0598	0.0045	0.1137	0.0471	0.0469	0.1522	0.05570

***, ** and * indicate significance at the 1%-, 5%- and 10%-confidence level, respectively.

A first point to mention is that the variable *R* for the Korean sample and *GDP* for the Indonesian sample are omitted, since both variables missed a substantial amount of data. After running regression with and without both variables, there were displayed significant different coefficients. For the Norwegian sample, the variable *R* also misses a part of the full sample data. Including or excluding this variable however, led to no different results.

As in the earlier analyses it turns out that El Niño expressed in SOI value has no effect on the

[18] Each country has the variables Imports and Exports depicted in its own currency, except for Peru and Indonesia which are stated in millions of dollars ($).

Canadian as well as all the European stock market indices. In addition to that, the 6-months lagged effect of El Niño on the NYSE has also disappeared after controlling for several economic variables. A remarkable finding is that the effect of El Niño on the South-East Asian and Peruvian stock markets stays present for the negative coefficients (positive effect on returns), whereas the positive coefficients (negative effects) are no longer significant for the Japanese sample. This means that Korea, Peru and Indonesia are only positively impacted by the aftermath of an El Niño cycle after controlling for several factors which are also included in the research of Cashin et al., (2015). This positive effect does not correspond with the literature of how the countries are affected by an El Niño cycle. Certainly for the Indonesian IDX Composite and the Peruvian S&P/BVL expectations were that stock market returns were negatively affected. The distorted fishing industry in Peru and the ruined crops due to dehydration and bushfires loweres export levels, which in turn negatively influences GDP growth. It also lowers the total amount of imports because less money is earned. For the Japanese index, the same reasoning applies as stated below Table 4. In a later stadium after a cycle Japanese farmers might benefit from the wet monsoon season, which positively affects stock returns.

When looking at Sea Surface Temperature as an approximation of El Niño activity (Table E1), we find the same results for the North-American and European indices except for the Norwegian sample. 3 months after an El Niño strike, the returns on the MSCI Norway are affected significant negatively with 3.56% for every one unit increase in the Sea Surface Temperature. This relatively high percentage can again be explained by the fact that the temperature is less volatile and shows less exhorbitant values. Furthermore are Japan and Peru unaffected by El Niño activity when using SST as explanatory variable. This is contradictory to the results of Table 5. Korea and Indonesia are both affected by El Niño in more or less the same way as they are when using SOI as explanatory variable. The only remarkable point is that both indices are affected in an earlier stadium than they are when using SOI. Korea (0.0244) and Indonesia (0.0471) are both positively affected 6 months after a strike, whereas they are affected positively 9 months after a strike according to SOI predictors (-0.0122 and -0.0137, respectively). The difference in magnitude again comes from the difference in variable values. In addition to that, Korea's KSI is negatively affected at the moment of impact (-1.74%). This is in line with the literature that Korea is struck by typhoons in the beginning of an El Niño event.

When zooming in on the significance of the added control variables, there is fairly the same pattern in Table 5 as well as Table E1. Firstly, the 1-month rent has a negative impact on stock market returns. This is in line with earlier research by Flannery & James (1984), who also found an inverse relationship between interest rates en stock market prices. Secondly, in both analyses there is found an overall negative relationship between the total amount of import and stock market returns. This result is also as expected by the stated literature. According to Grossman & Levinsohn

(1989), do positive surprises on import prices (i.e. lower import prices) favorably affect stock market returns. This means that lower total import also favorably affects stock market returns, which is the inverse relationship that is found. Thirdly, the stock market returns of Germany, Korea and Peru are significant positively affect by the total amount of monthly export. Most of the other countries show the same sign and magnitude, but lack statistical significance. This finding is contradictory to the literature which states that more export due to a currency appreciation moves against the performance of stock markets. Furthermore can the theory of an indirect effect of export on stock markets via GDP be rejected, because GDP shows no significant results. Lastly, shows the dummy variable for the January effect significance for the Canadian, Dutch, UK and Peruvian index. Higher returns in January can be obtained on these indices. This effect is primarily present among small-cap firms (Thaler, 1987) or firms that tend to window-dress their annual numbers (Haugh & Hirschey, 2006).

A last time-series analysis will add the 1-month lagged return to the regression. If the 1-month lagged return indeed has an effect on the current return and this variable is not incorporated in the regression, it means that the effect is captured by one of the other control variables which is known as the omitted variable bias. Adding the lagged return to the regression thus serves as a measure to check the reliability of the coefficients' statistical significance and gets rid of the autocorrelation in a model. The results are shown in Table 6 (SOI) and Table E2 in Appendix E (SST).

Table 6: Multivariate regression with SOI after adding 1-month lagged return

Table 6 shows the results of the multivariate regression per country for the full sample period. The dependent variable is the return of the index as stated in Regression 3. The independent variables are the Southern Oscillation index (SOI) on impact and the same variable with a lag of 3, 6, 9 and 12 months. GDP represents the monthly GDP in millions for each country in its own currency, R is the 1-month interest rate, CPI is a monthly index number, import and export are depicted monthly in millions[19], D_{jan} is a dummy variable that equals 1 in the month January and 0 otherwise and R_{t-1} is the1-month lagged return on the index. The numbers in parentheses represent the p-values of the coefficients.

	USA	*Canada*	*Netherlands*	*Germany*	*UK*	*Norway*	*Japan*	*Korea*	*Peru*	*Indonesia*
C	0.0138	0.0316	0.2960**	0.7325**	0.1197*	0.0735	0.2671**	0.0124	-0.1008	0.1135
	(0.5346)	(0.5322)	(0.0115)	(0.0106)	(0.0930)	(0.5915)	(0.0106)	(0.3183)	(0.2655)	(0.6600)
SOI	-0.0027	-0.0021	-0.0034	0.0017	-0.0022	0.0013	-0.0035	-0.0009	-0.0173**	-0.0021
	(0.2028)	(0.4388)	(0.4532)	(0.6697)	(0.4191)	(0.7957)	(0.2799)	(0.8028)	(0.0137)	(0.7277)
SOI_{t-3}	-0.0004	0.0036	-0.0022	-0.0018	0.0028	0.0055	0.0033	0.0081*	0.0027	0.0366
	(0.8581)	(0.2238)	(0.6620)	(0.6956)	(0.3488)	(0.3313)	(0.3549)	(0.0536)	(0.7294)	(0.5932)
SOI_{t-6}	0.0050	0.0015	0.0034	0.0035	-0.0001	0.0040	0.0041	0.0034	0.0129	0.0074
	(0.0388)	(0.6065)	(0.4910)	(0.4349)	(0.9781)	(0.4743)	(0.2510)	(0.4149)	(0.1005)	(0.2935)
SOI_{t-9}	-0.0036	-0.0008	-0.0056	-0.0062	-0.0023	-0.0007	-0.0081**	-0.0018***	-0.0134*	-0.0127*
	(0.1394)	(0.7764)	(0.2470)	(0.1636)	(0.4446)	(0.9069)	(0.0251)	(0.0051)	(0.0824)	(0.0661)
SOI_{t-12}	0.0007	-0.0037	-0.0024	0.0022	-0.0017	-0.0028	-0.0007	0.0028	-0.0064	0.0013
	(0.7300)	(0.1654)	(0.5824)	(0.5762)	(0.5394)	(0.5806)	(0.8172)	(0.4502)	(0.3620)	(0.8315)
GDP	9.4E-10	1.0E-07	1.3E-06	-1.1E-06**	-1.2E-07	3.5E-07	8.9E-11	1.94E-11	1.2E-06	
	(0.8640)	(0.1557)	(0.2965)	(0.0396)	(0.3868)	(0.3612)	(0.6069)	(0.9505)	(0.5109)	
R	-0.0005	-0.0040**	-0.0213***	-0.0094	-0.0020	-0.0124***	-0.0047**		0.0034**	-0.0008
	(0.5490)	(0.0125)	(0.0006)	(0.0083)	(0.1546)	(0.0001)	(0.0147)		(0.0449)	(0.1838)
CPI	-4.00E-05	-0.0008	-0.0046*	-0.0020	-0.0013	-0.0015	-0.0028*	5.84E-06	0.0006	0.0001
	(0.8898)	(0.4743)	(0.0650)	(0.4189)	(0.2690)	(0.3577)	(0.0755)	(0.9948)	(0.7297)	(0.8000)
IMPORT	-3.9E-07	-2.9E-06	-4.3E-06	-7.3E-07	-2.5E-06	-1.9E-06	2.8E-09	-6E-06***	-1E-04***	-6.66E-06
	(0.1822)	(0.1386)	(0.5521)	(0.5817)	(0.4958)	(0.1042)	(0.6195)	(0.0068)	(0.0015)	(0.1738)
EXPORT	2.8E-08	2.0E-08	-2.6E-06	3.2E-06*	1.1E-06	-4.7E-07	-6.8E-09	5.6E-05**	5.9E-05***	5.49E-06
	(0.2281)	(0.8425)	(0.7039)	(0.0670)	(0.3129)	(0.5547)	(0.3347)	(0.0152)	(0.0017)	(0.3798)
Djan	6.8E-05	0.0167	0.0266*	0.0121	0.0198**	0.0207	0.0031	0.0101	0.0435*	0.0262
	(0.9923)	(0.0535)	(0.0588)	(0.3450)	(0.0242)	(0.2184)	(0.7856)	(0.3942)	(0.0591)	(0.1911)
R_{t-1}	0.0518	0.0654	-0.0757	0.0036	-0.0051	-0.0098	0.0296	0.0622	-0.0060	0.1017
	(0.2540)	(0.2376)	(0.2691)	(0.9526)	(0.9259)	(0.8870)	(0.5441)	(0.1702)	(0.9199)	(0.1304)
R^2	0.0303	0.0661	0.1103	0.0599	0.0454	0.1138	0.0480	0.0532	0.1522	0.0654

***, ** and * indicate significance at the 1%-, 5%- and 10%-confidence level, respectively.

When comparing the results of Table 5 and E1 with the results of Table 6 and E2, there can be observed that the significance, magnitude and sign of the coefficients do not alter very much. The coefficients regarding the SST and SOI variables do not lose their statistical significance. In addition to that, one finds that Peru experiences a positive effect due to an El Niño of the magnitude 0.0173 and

[19] Each country has the variables Imports and Exports depicted in its own currency, except for Peru and Indonesia which are stated in millions of dollars ($).

Korea's KSI gains a decrease in stock returns 3 months after a cycle (0.0081). When zooming in on the statistical significance, there is not one conclusion to be drawn. Where one coefficient become more significant, another coefficient loses some of its significance. Furthermore, is in none of the two analyses a significant 1-month lagged return to be found. This is contrary to the findings of Saunders (1993) and Cao & Wei (2005), but there must be noted that we use monthly returns, which makes it much more logical why last month's returns do not explain anything about this month's returns. Lastly, the R^2 of the models show an increase compared to the models without the lagged dependent variable.

With the knowledge of the above done analyses, it is made possible to test the third hypothesis:

3. *"The effect of El Niño on stock market returns disappears after controlling for several control variables"*

After incorporating several control variables which are to be said to have an impact on stock market returns and adding a lagged dependent variable, El Niño's effect on stock market returns still has a significant effect on the Japanese NIKKEI225, the Korean KSI, the Peruvian S&P/BVL and the Indonesian IDX Composite. The third hypothesis will thus be rejected.

5.1.2 Subsamples

In order to test if the found effects in Section 5.1.1 come from a specific period and to check if the effect of El Niño on stock markets is currently still present, the full sample is divided in three subsamples. The first period is only applicable to the US dataset, which is from 1950-1970. The second subsample goes from 1970-2000 and the last subsample with the big financial crisis incorporated in it and contains the years 2000-2015. The motivation for the distribution of the subsamples is to be found in the Section Methodology. Expected is that in the latter subsample more significant results concerning the El Niño variable will be found since El Niño cycles are reinforced due to global greenhouse warming and this become more and more a global issue. Furthermore, a dummy variable in the 2000-2015 subsample is created which depicts the worldwide financial crisis. This dummy variable is equal to one if it concerns a month in the period 2007-2009 and zero otherwise. This is derived from Kuppuswamy & Villalonga (2016) and Erkens, Hung, & Matos (2012) and captures the possible effect of the crisis on the retuns of the indices. For simplicity, only the Tables regarding the SOI data are shown in the main text. Tables of the subsamples regarding the SST anomaly values are displayed in Appendix F.

Table 7 shows the results of the first subsample analysis. Note that the 1-month interest rate variable is ommitted from this regression, since there are not sufficient datapoints in this timespan to give representative results. When looking at the results, there can be seen that throughout this analysis no statistical significant coefficients are to be found. In fact, in both Panel A and Panel B the El Niño variables are far from significant. Also when looking at the economical significance of these variables, there is no unambiguous conclusion to be drawn. The sign of the coefficients changes from positive to negative throughout the lagged periods. This is in line with our expectation of the effect of El Niño on the US stock markets during the 1950-1970 period, since this period shows less frequent and less intense El Niño activity (see Figure 1A and 1B).

Table 7: Multivariate regression of 1950-1970 subsample

Table 7 shows the results of the multivariate regression for the 1950-1970 period. The dependent variable is the return of the index as stated in Regression 3. The independent variables are the Southern Oscillation Index (SOI) on impact and the same variable with a lag of 3, 6, 9 and 12 months. GDP represents the monthly GDP in millions of Dollars, CPI is a monthly index number, import and export are depicted monthly in millions, D_{jan} is a dummy variable that equals 1 in the month January and 0 otherwise and R_{t-1} is the1-month lagged return on the index. USA_1 and USA_2 represent the analyses without and with including the 1-month lagged return, respectively. The numbers in parentheses represent the p-values of the coefficients.

A	C	SOI	SOI $_{t-3}$	SOI $_{t-6}$	SOI $_{t-9}$	SOI $_{t-12}$	GDP	CPI	IMPORT	EXPORT	D_{jan}	R $_{t-1}$	R^2
USA_1	-0.1135	0.0005	0.0013	0.0034	0.0005	-0.0026	2.37E-08	0.0041	-8.95E-06	-2.26E-06	-0.0034		0.0349
	(0.3201)	(0.8860)	(0.7089)	(0.3277)	(0.8837)	(0.4451)	(0.2676)	(0.4018)	(0.6022)	(0.1635)	(0.7236)		
USA_2	-0.1166	0.0004	0.0013	0.0033	0.0005	-0.0024	2.38E-08	0.0041	-8.71E-06	-2.28E-06	-0.0039	0.0632	0.0389
	(0.3076)	(0.9119)	(0.6991)	(0.3375)	(0.8832)	(0.4848)	(0.2663)	(0.3924)	(0.6122)	(0.1596)	(0.6885)	(0.4076)	
B	**C**	**SST**	**SST $_{t-3}$**	**SST $_{t-6}$**	**SST $_{t-9}$**	**SST $_{t-12}$**	**GDP**	**CPI**	**IMPORT**	**EXPORT**	**D_{jan}**	**R $_{t-1}$**	**R^2**
USA_1	-0.0698	-0.0008	-0.0126	0.0079	-0.0006	0.0107	1.92E-08	0.0026	-6.94E-06	-1.79E-06	-0.0023		0.0506
	(0.5078)	(0.9239)	(0.2114)	(0.4430)	(0.9559)	(0.2782)	(0.3669)	(0.5771)	(0.6795)	(0.2588)	(0.8175)		
USA_2	-0.0726	-0.0006	-0.0124	0.0077	-0.0005	0.0099	1.95E-08	0.0026	-6.86E-06	-1.82E-06	-0.0026	0.0429	0.0523
	(0.4925)	(0.9456)	(0.2180)	(0.4530)	(0.9627)	(0.3195)	(0.3609)	(0.5671)	(0.6839)	(0.2520)	(0.7934)	(0.5763)	

***, ** and * indicate significance at the 1%-, 5%- and 10%-confidence level, respectively.

Since the first subsample analysis has shown no significant results, we analyze the second subsample period, consisting of the years 1970-2000. Table 8n shows the results for the regression with the SOI predictor added to it. Results regarding the SST analysis are to be found in Appendix F. Because the analysis in Table 6 and Table E1 has shown that adding the 1-month lagged return had little effect on the change of the coefficients and its significance, the results of this analysis for the subsample are omitted. We have included this lagged dependent variable in the regression and found that again there was little difference when adding this variable. The blank spaces in the Table come from the absence of data[20].

A first interesting finding is the significance of the 6-months lagged SOI variable. During the period of 1970-2000, every country except for Norway and Japan are statiscally significant affected by El Niño 6 months after it has struck. Furthermore, the sign for all coefficients is positive which

[20] This is confirmed in Table 2: Descriptive statistics of control variables

means that El Niño has a negative effect on the stock market returns. The magnitude ranges from 0.76% (USA) to 3.27% (Peru). For Peru, this negative effect is in line with the literature on El Niño effets, but a striking result is the negative effect on European stock markets sinces these countries are less effected by the climatological effects of El Niño, but which should mainly be affected positive by trading spillover. Nevertheless, preliminary the German DAX and the Dutch AEX experience significant stock market decreases when El Niño strengthens. The effect of El Niño on the UK FTSE is weakenend by a positive effect on its returns on the moment of impact. This is also the case for the Peruvian index. These results are different from the ones obtained during the full sample analysis. A first large difference is that the North-American and European countries are significantly affected in this shorter time period. A second difference is that indices that were affected by El Niño in the full sample analysis are now affected three months earlier which also led to a change of sign (i.e. from a positive effect to a negative effect for Peru, Korea and Indonesia).

When also including the results of the SST predictor analysis (See Appendix F, Table F1) we find approximate the same results in magnitude and sign, but the effect index returns occurs 9 months after the start of the cycle. This is contradictory to the full sample analysis where the effect of SST on stock market returns came one lagged period earlier compared to using SOI as predictor. Again show the US and the Netherlands and Norway significant negative coefficients, which implies a negative effect on the returns. Japan and Peru also experience a negative effect on impact, which does not correspond to the results of Table 8 but does with the stated literature. Lastly, the effect of Indonesia 9 months (-0.0659) and 12 months (0.0644) after a start of El Niño cancel each other out more or less. The positive effect on the Korean KSI according to Table 8 arises three months earlier when using Sea Surface temperature, but is approximately the same when looking at the magnitude. Looking at the results of the control variables, we only find the 1-month interest rate to have a significant negative effect on stock markets which was also the case in the full sample analysis. The January effect is mainly present on the Indonesian stock exchange, which can be explained by the fact that this anomaly occurs mainly at small cap firms. Since Indonesia is a starting index in the 1970-2000 period, a relative large amount of smaller cap firms is expected in the IDX composite.

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Table 8: Multivariate regression of 1970-2000 subsample

Table 8 shows the results of the multivariate regression for the 1970-2000 period. The dependent variable is the return of the index as stated in Regression 3. The independent variables are the Southern Oscillation Index (SOI) on impact and the same variable with a lag of 3, 6, 9 and 12 months. GDP represents the monthly GDP in its own currency, R is the 1-month interest rate, CPI is a monthly index number, import and export are depicted monthly in millions and D_{jan} is a dummy variable that equals 1 in the month January and 0 otherwise. The numbers in parentheses represent the p-values of the coefficients.

	USA	*Canada*	*Netherlands*	*Germany*	*UK*	*Norway*	*Japan*	*Korea*	*Peru*	*Indonesia*
C	0.0876	0.0452	0.0572	0.3271	0.0617	-0.0482	0.0048	-0.0003	-0.4116	0.0313
	(0.1685)	(0.8855)	(0.5112)	(0.5658)	(0.6534)	(0.3940)	(0.9771)	(0.9856)	(0.2059)	(0.1450)
SOI	-0.0028	-0.0038	-0.0034	-0.0041	-0.0074*	-0.0021	-0.0004	-0.0020	-0.0294*	0.0081
	(0.3081)	(0.3424)	(0.4627)	(0.4571)	(0.0869)	(0.6849)	(0.9246)	(0.6795)	(0.0603)	(0.3797)
SOI_{t-3}	-0.0017	0.0006	-0.0025	-0.0103	0.0039	0.0025	0.0060	0.0084	0.0014	0.0029
	(0.5644)	(0.8780)	(0.6158)	(0.0915)	(0.3725)	(0.6645)	(0.1897)	(0.1180)	(0.9319)	(0.7638)
SOI_{t-6}	0.0076**	0.0110***	0.0114**	0.0240***	0.0088*	0.0047	0.0058	0.0115**	0.0327*	0.0174*
	(0.0116)	(0.0100)	(0.0251)	(0.0001)	(0.0504)	(0.4173)	(0.2147)	(0.0349)	(0.0585)	(0.0751)
SOI_{t-9}	-0.0030	-0.0007	-0.0048	-0.0156**	-0.0056	0.0036	-0.0042	-0.0168***	-0.0098	-0.0159
	(0.3230)	(0.8740)	(0.3395)	(0.0134)	(0.2114)	(0.5410)	(0.3676)	(0.0021)	(0.5639)	(0.1037)
SOI_{t-12}	0.0004	-0.0035	-0.0005	0.0075	-0.0029	0.0007	0.0025	0.0043	-0.0156	0.0152
	(0.8750)	(0.3625)	(0.9089)	(0.1882)	(0.5006)	(0.8966)	(0.5624)	(0.3853)	(0.3239)	(0.0811)
GDP	-1.65E-08	8.03E-08		-9.57E-07	4.24E-08	3.36E-07	-4.01E-10	1.22E-09*	1.03E-05	
	(0.2511)	(0.8230)		(0.4948)	(0.9474)	(0.1935)	(0.1562)	(0.0831)	(0.3193)	
R	-0.0010	-0.0043*	-0.0044*	-0.0017	-0.0011		-0.0035		0.0046	
	(0.3081)	(0.0662)	(0.0786)	(0.8077)	(0.5953)		(0.1234)		(0.1142)	
CPI	2.78E-04	-0.0008	-8.79E-05	0.0015	-0.0014	2.64E-05	0.0029	-0.0007	-0.0014	
	(0.4488)	(0.5822)	(0.9593)	(0.7780)	(0.4627)	(0.9677)	(0.3259)	(0.5881)	(0.7008)	
IMPORT	6.42E-07	-2.18E-06	-8.49E-06	1.54E-07	2.44E-06	-4.81E-06	-9.71E-09	-1E-05***	-0.0002	7.91E-06
	(0.5604)	(0.7720)	(0.4877)	(0.9643)	(0.8334)	(0.1405)	(0.4173)	(0.0022)	(0.4804)	(0.6605)
EXPORT	2.64E-08	3.26E-08	6.71E-06	2.67E-06	7.37E-08	-1.45E-06	-2.14E-08	7.36E-08	6.04E-05	-1.04E-05
	(0.6501)	(0.9377)	(0.5597)	(0.5372)	(0.9792)	(0.5081)	(0.1647)	(0.9917)	(0.8382)	(0.4775)
D_{jan}	0.0090	0.0090	0.0234	-0.0179	0.0166	0.0002	-0.0179	-0.0059	0.0735	0.0568*
	(0.3192)	(0.4777)	(0.1344)	(0.3574)	(0.2381)	(0.9918)	(0.2821)	(0.7391)	(0.1947)	(0.0579)
R^2	0.0305	0.1025	0.0621	0.1985	0.0827	0.0261	0.0789	0.0839	0.2293	0.0837

***, ** and * indicate significance at the 1%-, 5%- and 10%-confidence level, respectively.

The last analysis consists of regressions on the dataset when limiting it to the period 2000-2015. The results are shown in Table 9 (SOI) and Table F2 (SST). As stated earlier, a dummy variable is added to capture the possible effect of the great financial crisis. Since this crisis stretches across a significant part of the subsample, not adding this variable might distort the analysis which might lead to biased results. The dummy variable Dum_{crisis} equals one in the years 2007-2009 and zero otherwise, because these are the most intense years of the crisis. When looking at the results, one immediately notices that when using both SOI as predictor as well as SST as predictor, it yields only two significant El Niño coefficients. Only Japan's stock market returns are significantly positive affected by El Niño, 9 months after a cycle (-0.0111). Korea's KSI is affected negatively on the moment of impact (0.0259). Both effects were also found in the full sample analysis. The theory that stock markets are more intense affected by El Niño activity in the latter subsample because of increasing global warming can thus be rejected. Furthermore, the 1-month interest rate is strongly significant across the different datasets.

Table 9: Multivariate regression of 2000-2015 subsample

Table 9 shows the results of the multivariate regression for the 2000-2015 period. The dependent variable is the return of the index as stated in Regression 3. The independent variables are the Southern Oscillation Index (SOI) on impact and the same variable with a lag of 3, 6, 9 and 12 months. GDP represents the monthly GDP in its own currency, R is the 1-month interest rate, CPI is a monthly index number, import and export are depicted monthly in millions and D_{jan} is a dummy variable that equals 1 in the month January and 0 otherwise. D_{crisis} is a dummy variable that equals one in the years 2007-2009 and zero otherwise The numbers in parentheses represent the p-values of the coefficients.

	USA	*Canada*	*Netherlands*	*Germany*	*UK*	*Norway*	*Japan*	*Korea*	*Peru*	*Indonesia*
C	-0.1629	-0.2094*	0.3048	0.7803*	0.1297	0.3768*	0.0331*	-0.0681	-0.0498	0.0281
	(0.3391)	(0.0935)	(0.2230)	(0.0525)	(0.3500)	(0.0663)	(0.0999)	(0.6815)	(0.7916)	(0.5178)
SOI	0.0001	-0.0029	0.0002	0.0060	0.0006	-0.0003	-0.0015	0.0032	-0.0084	-0.0041
	(0.9803)	(0.4451)	(0.9768)	(0.2739)	(0.8760)	(0.9630)	(0.7759)	(0.6007)	(0.2694)	(0.4858)
SOI t-3	0.0044	0.0059	0.0012	0.0061	0.0029	0.0061	0.0032	0.0053	0.0046	0.0042
	(0.3124)	(0.1801)	(0.8333)	(0.3265)	(0.5078)	(0.3332)	(0.5707)	(0.4402)	(0.5896)	(0.5189)
SOI t-6	0.0015	-0.0073	-0.0064	-0.0081	-0.0072	-0.0057	0.0011	-0.0082	0.0037	-0.0065
	(0.7255)	(0.1086)	(0.2737)	(0.1889)	(0.1023)	(0.3694)	(0.8464)	(0.2452)	(0.6660)	(0.3339)
SOI t-9	-0.0003	-0.0016	0.0006	0.0024	0.0010	-0.0019	-0.0111*	-0.0036	-0.0135	-0.0019
	(0.9517)	(0.7135)	(0.9111)	(0.6945)	(0.8124)	(0.7596)	(0.0547)	(0.5981)	(0.1124)	(0.7677)
SOI t-12	0.0021	-0.0053	-0.0060	-0.0041	-0.0031	-0.0041	0.0009	0.0007	-0.0010	-0.0063
	(0.5970)	(0.1835)	(0.2513)	(0.4593)	(0.4400)	(0.4657)	(0.8584)	(0.9153)	(0.8901)	(0.2756)
GDP	3.82E-08*	-8.85E-08	8.36E-07	4.51E-08	3.25E-07	-4.05E-07	-8.91E-10	-1.50E-09	-1.12E-06	
	(0.0575)	(0.7457)	(0.6787)	(0.9596)	(0.4531)	(0.4309)	(0.2337)	(0.1910)	(0.6228)	
R	-0.0025	0.0038	-0.0221***	-0.0275***	-0.0090	-0.0155***	-0.0881***	0.0047	-0.0072	-0.0037*
	(0.4267)	(0.4381)	(0.0012)	(0.0044)	(0.0089)	(0.0000)	(0.0015)	(0.1542)	(0.1579)	(0.0990)
CPI	-0.0015	0.0050	-0.0041	-0.0096*	-0.0031	-0.0001	-0.0068*	0.0051	0.0020	-2.75E-05
	(0.3409)	(0.2263)	(0.1247)	(0.0615)	(0.1095)	(0.9491)	(0.0967)	(0.2781)	(0.5617)	(0.9631)
IMPORT	-7.09E-07	-7.14E-06	4.85E-06	-1.50E-06	-3.07E-06	-5.51E-07	1.67E-08	-7.0E-06**	-5.8E-05*	-1.1E-05**
	(0.1111)	(0.0319)*	(0.5287)	(0.3858)	(0.4676)	(0.6853)	(0.1200)	(0.0156)	(0.0537)	(0.0165)
EXPORT	2.96E-08	7.45E-08	-3.28E-06	3.54E-06	1.20E-06	1.68E-08	6.16E-09	7.2E-06**	4.1E-05**	1.16E-05**
	(0.5638)	(0.7368)	(0.6404)	(0.1102)	(0.3949)	(0.9846)	(0.5358)	(0.0373)	(0.0393)	(0.0305)
Djan	-0.0119	0.0179	0.0202	0.0057	0.0147	0.0230	0.0284*	0.0183	0.0171	0.0277
	(0.3121)	(0.1541)	(0.2078)	(0.7379)	(0.2135)	(0.1945)	(0.0988)	(0.3440)	(0.4886)	(0.1218)
Dcrisis	-0.0079	-0.0165	0.0164	0.0343*	0.0005	0.0190	0.0194	0.0126	-0.0047	-0.0015
	(0.4575)	(0.1093)	(0.3618)	(0.0671)	(0.9609)	(0.2218)	(0.2225)	(0.3658)	(0.7737)	(0.9107)
R2	0.0495	0.1232	0.1087	0.1176	0.0908	0.1472	0.1607	0.0782	0.1276	0.0933

***, ** and * indicate significance at the 1%-, 5%- and 10%-confidence level, respectively.

Also the amount of import and export have a significant effect during the 2000-2015 period, which might come from the fact the import and export are heavily influenced due to the economic crisis where countries imported and exported less goods due to liquidity problems. The sign of both variables is the same as in the full sample analysis. Lastly, only Germany and Canada's stock market indices are affected by the economic crisis during the 2007-2009 period. Canada's returns are negatively affected in periods of crisis, which is as expected whereas Germany's stock returns are 4.00% higher compared to periods of non-crisis. This effect has not been found during earlier researches, such that there is no scientific explanation for this result. The R^2 of the models have again increased compared to Table 6 and Table E2, which is logical because another variable is added to the regression.

With the results of Subsection 5.1.2 it is made possible to give an answer to the last stated time-series hypothesis which is stated as follows:

4. *"the 2000-2015 subsample shows a more significant effect of El Niño on stock returns compared to the subsamples of 1950-1970 and 1970-2000."*

The 1950-1970 subsample which is only applicable to the NYSE shows no significant results regarding the El Niño predictors. The same applies for almost every index in the latest 2000-2015 subsample. The middle subsample of 1970-2000 however, shows significant effect on almost every index. The only difference when using either SOI or SST as El Niño variable is that the effect occurs in a earlier stadium (after 6 months) when using SOI compared to using SST (effect after 9 months). The sign and magnitude are approximately the same (see Table 8 and Table F1). A possible explanation for this delayed SST effect might come from the fact that SOI is a continuous variable whereas SST is a dummy variable. Further research might create a dummy variable of SOI in order to check their differences. This paper paper follows the established literature of using SOI as continuous (Cashin, Mohaddes, & Raissi, 2015). The fourth hypothesis will thus be rejected. During the 1970-2000 period, El Niño has a more severe effect on stock markets compared to the 1950-1970 and 2000-2015 period.

5.2 Cross-section

This Subsection shows the results of the cross-section analysis between the 15% most severe El Niño months and the 15% mildest ones. The motivation behind this analysis is to test if the found effects in the time-series analysis are explicitly due to severe El Niño periods. By comparing the returns during the most heavy months with the returns during the mildest months we can check if the effects of El Niño on index returns are present during every El Niño strike or only during the most intense periods. As explained in the methodology, we will first compute z-statistics to test on the difference in means and the difference in frequency of positive returns. The latter test is to see possible return difference is driven by outliers. If heavier El Niño cycles are associated with lower returns for example, we would expect that the percentage of positive returns is low in the lowest bin (i.e. most intense El Niño periods). This analysis follows the method of Cao & Wei (2005). The results are reported in Table 10 below.

In the lowest bin are the months which had the most intense El Niño periods. This leads to the higher bin being the sample with the mildest periods in which an El Niño is present. There is no clear overall correlation between the severity of El Niño and stock market returns, but this was alsno not expected. Since every country is affected by El Niño in its own manner, correlations were not expected to be uniform. According to the literature, Canada and the European countries experience positive effects from El Niño which means that the Bin_{low} returns would show higher mean returns than the Bin_{high}. However, this effect is not observed but there must be noted that there is found no statistical significant difference on the mean returns.

Table 10: Analysis on statistical difference of means

Table 10 shows the results of z-tests on the difference of means between the 15% returns in months with highest El Niño (Bin_{Low}) and the 15% returns in months with mildest El Niño (Bin_{High}) . N is the number of observations. The numbers in parentheses represent the p-values of the coefficients.

		Bin_{Low}	N_{low}	Bin_{High}	N_{High}	P-score(H,L)
USA	*mean returns*	0.0170	82	0.0056	82	0.0445**
	% of + returns	0.6951		0.6585		0.3082
Canada	*mean returns*	0.0061	82	0.0065	82	0.4773
	% of + returns	0.5610		0.6220		0.2131
Netherlands	*mean returns*	0.0072	60	0.0035	66	0.3673
	% of + returns	0.5500		0.5758		0.3855
Germany	*mean returns*	0.0024	82	0.0125	82	0.1268
	% of + returns	0.4878		0.5732		0.1358
UK	*mean returns*	0.0091	82	0.0084	82	0.4590
	% of + returns	0.6585		0.6341		0.3722
Norway	*mean returns*	0.0056	82	0.0065	82	0.4668
	% of + returns	0.5610		0.5732		0.4374
Japan	*mean returns*	0.0061	77	0.0090	79	0.4063
	% of + returns	0.4675		0.4810		0.4331
Korea	*mean returns*	-0.0011	82	0.0078	82	0.1479
	% of + returns	0.4878		0.5854		0.0987*
Peru	*mean returns*	0.0520	47	0.0619	52	0.3614
	% of + returns	0.6809		0.5962		0.1894
Indonesia	*mean returns*	0.0031	57	0.0029	66	0.4944
	% of + returns	0.5263		0.4848		0.3231

***, ** and * indicate significance at the 1%-, 5%- and 10%-confidence level, respectively.

Table 10 only reports two significant results, at the NYSE and the Korean KSI. For the USA, this means that returns are significantly higher in months that a severe El Niño period is present. Since the net effect on the USA is not obvious in the stated literature, we can infer that NYSE index returns are positively correlated with the severity of an El Niño cycle. The net effect of the increasing typhoons and the growing agricultural sector due to increasing rainfall is also hard to predict for the Korean economy. Table 10 shows that the returns on the KSI are higher when El Niño is less aggressive, this result is only economically significant. When looking at the proportion of positive returns per month, we find a statiscally significant effect meaning that there are more positive months in terms of returns on the KSI in months when El Niño is relatively mild.

A clear answer to the last stated hypothesis is hard to formulate with only the results of Table 10 on hand. To give more insight in the effect of more severe El Niños compared to milder ones, we will run a regression in which we focus on only the SOI variables. This regression will show if milder El Niño periods have the same effect on returns as in periods where El Niño strikes intense.

Table 11 displays the output of these multivariate regressions. For simplicity, we have only displayed the coefficients regarding the El Niño variable but the regressions have included all possible variables[21]. Panel A shows the results of the sample where the months of most severe El Niño periods are incorporated, whereas Panel B shows the milder periods. When comparing both Panels, it is first noticed that El Niño has much more significant effect on stock markets over the world in months that El Niño has been more intense. The European indexes experience a first positive effect on the returns of the index in the month that El Niño strikes and a second positive effect 9 months after impact. This is in line with the positive spillover theory. The cumulative magnitude is around 6-7% for a one unit increase in SOI value. The South-East Asian indexes (NIKKEI225, KSI and ISX Composite), undergo a decrease in stock markets return due to heavier El Niño cycle. This indicates that the negative consequences of El Niño (e.g. typhoons) overflow the positive effects from a growing agricultural sector (e.g. larger amount of crops). A remarkable result is that the Peruvian index experiences no statistical consequences of a heavy El Niño cycle, whereas the literature states that Peru is largely affect by an El Niño. Lastly, it is found that 12 months after a strike, all included indexes are affected negatively either economically significant and in 50% of the cases also statistically significant. The R^2 of the models has increased largerly compared to previous analyses. This comes from the fact that relatively more variables are present to explain the variation in the model. In panel B, we find that only the NYSE and KSI are affected at some point in time by El Niño. When focusing on the KSI, there can also be seen that the effect 6 (0.0249) and 9 (-0.0223)

[21] Since some control variables of a country have insufficient observations, these variables have been omitted from the regression. For both the high bin and the low bin this concerns: *GDP* of The Netherlands, *R* of Norway and Korea and *GDP*, *R* and *CPI* of Indonesia.

months after impact almost cancel each other out, leaving the net effect of El Niño on KSI returns nihil. The NYSE experiences some negative effect 6 months after a cycle when the El Niño cycle has been relatively mild.

Table 11: Multivariate regression on highest and lowest bin

Table 11 shows the results of the multivariate regressions of n the 15% returns in months with highest El Niño (Panel A, Bin_{Low}) and the 15% returns in months with mildest El Niño (Panel B, Bin_{High}) . Only the coefficients of El Niño predictors are shown. N is the number of observations. The numbers in parentheses represent the p-values of the coefficients.

A		*USA*	*Canada*	*Netherlands*	*Germany*	*UK*	*Norway*	*Japan*	*Korea*	*Peru*	*Indonesia*
Most severe	*C*	-0.0068	-0.1026	0.1722	0.6042	0.0634	-0.1015	0.2385	0.0602	-0.1463	-0.0015
		(0.9050)	(0.5454)	(0.3230)	(0.4167)	(0.8676)	(0.2135)	(0.3704)	(0.2254)	(0.6173)	(0.9808)
	SOI	0.0009	-0.0310**	-0.0456**	-0.0576***	-0.0254	-0.0473**	-0.0185	0.0157	-0.0560	-0.0191
		(0.9251)	(0.0489)	(0.0118)	(0.0061)	(0.1461)	(0.0199)	(0.2595)	(0.5037)	(0.2670)	(0.5625)
	SOI_{t-3}	-0.0010	0.0050***	0.0055	-0.0019	0.0109	-0.0055	0.0181**	0.0127	0.0319	0.0104
		(0.8388)	(0.4511)	(0.5416)	(0.8349)	(0.1822)	(0.5794)	(0.0308)	(0.2881)	(0.1537)	(0.4947)
	SOI_{t-6}	-0.0055	0.0022	0.0107	0.0254**	0.0020	0.0056	-0.0047	0.0028	-0.0223	-0.0016
		(0.3122)	(0.7779)	(0.2841)	(0.0163)	(0.8169)	(0.6103)	(0.5996)	(0.8230)	(0.3677)	(0.9205)
	SOI_{t-9}	-0.0018	0.0004	-0.0219**	-0.0187**	-0.0155*	0.0050	-0.0094	-0.0184	0.0255	-0.0182
		(0.7168)	(0.9591)	(0.0177)	(0.0492)	(0.0594)	(0.6228)	(0.2478)	(0.1312)	(0.2636)	(0.2450)
	SOI_{t-12}	0.0082*	0.0056	0.0127	0.0168*	0.0155*	0.0063	0.0142*	0.0216*	0.0010	0.0306**
		(0.0966)	(0.4195)	(0.1833)	(0.0675)	(0.0705)	(0.5503)	(0.0877)	(0.0701)	(0.9664)	(0.0425)
	Obs	77	48	60	47	48	71	70	77	41	57
	R^2	0.1897	0.2439	0.3293	0.4629	0.2887	0.1798	0.2056	0.1477	0.3346	0.1144
B											
Mildest	*C*	0.1072	0.0363	0.0112	1.0897	0.2310	-0.0039	0.0777	0.0544	0.5083	-0.0687
		(0.2716)	(0.8063)	(0.9443)	(0.1771)	(0.2971)	(0.9640)	(0.8123)	(0.3456)	(0.1181)	(0.1848)
	SOI	0.0043	0.0014	-0.0860	-0.0439	0.0180	-0.0391	0.0853	0.0222	-0.1274	-0.0971
		(0.9224)	(0.9680)	(0.1626)	(0.5584)	(0.6706)	(0.5185)	(0.1410)	(0.7135)	(0.3158)	(0.1610)
	SOI_{t-3}	-0.0017	0.0037	-0.0042	-0.0019	0.0008	0.0045	-0.0076	-0.0097	-0.0033	-0.0097
		(0.8461)	(0.5672)	(0.7155)	(0.8876)	(0.9177)	(0.6997)	(0.4857)	(0.4126)	(0.8975)	(0.4439)
	SOI_{t-6}	0.0146*	-0.0003	-0.0022	0.0078	0.0069	0.0033	0.0115	0.0249**	0.0232	0.0075
		(0.0504)	(0.9573)	(0.8170)	(0.5243)	(0.2937)	(0.7416)	(0.2246)	(0.0155)	(0.3202)	(0.4871)
	SOI_{t-9}	-0.0074	0.0034	-0.0096	-0.0172	-0.0047	-0.0062	-0.0117	-0.0223*	-0.0420	0.0028
		(0.3778)	(0.5964)	(0.3989)	(0.2258)	(0.5473)	(0.5824)	(0.2979)	(0.0505)	(0.1129)	(0.8267)
	SOI_{t-12}	0.0036	-0.0037	0.0037	0.0081	0.0013	0.0040	0.0057	0.0074	-0.0316	-0.0005
		(0.6322)	(0.5870)	(0.7180)	(0.5477)	(0.8679)	(0.6943)	(0.5716)	(0.4796)	(0.1839)	(0.9697)
	Obs	79	56	66	52	56	76	70	79	49	66
	R^2	0.1027	0.1283	0.0890	0.1055	0.1191	0.0335	0.1545	0.1521	0.5142	0.0714

***, ** and * indicate significance at the 1%-, 5%- and 10%-confidence level, respectively.

With this information, we are able to test the last stated hypothesis:

5. *"Periods of the most heavy El Niños do not affect stock market returns more than milder El Niño periods."*

The returns on the stock markets worldwide are definitely more affected during and after heavy El Niño cycles compared to periods of milder El Niños. The magnitude varies per stock index but a fact is that European countries experience positive effects from an El Niño on impact and in the aftermath, whereas the South-East Asian countries,who lay closer to the epicenter of El Niño, are affected in a negative manner. The North-American stock indexes of USA and Canada are to be net affected by a stronger El Niño in a negative and positive way, respectively. The magnitude of these statistical significant coefficients however turns out to be small. During and after milder El Niño periods (SOI around the value of -1), only the Korean KSI and American NYSE seem to be affected at a certain point in time but the first effect is cancelled out by a opposite effect of El Niño three months later. The NYSE experiences the same negative effect as when El Niño is stronger, but the effect is slightly larger in milder El Niño periods.

When looking from the point of view from an investors, possibilities might arise. Since the NOAA Climate center can predict El Niño activity with its severity, investors might benefit by taking a long position in the European indices, taking a short position in for example the Japanese NIKKEI225 and hold these positions for a longer period of time (i.e. in order to fully benefit from the effect of El Niño for about 12 months). There must be noted that this higher than normal returns can be obtained, ceterus paribus.

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6. Conclusion

This thesis focusses on the effect of the climatological phenomenon El Niño Southern Oscillation (ENSO), or simply 'El Niño' on stock markets returns around the globe. A proxy for a stock market is the leading index in a country. The countries involved are the USA, Canada, The Netherlands, Germany, UK, Norway, Japan, Korea, Peru and Indonesia. A research on this subject is interesting from several perspectives. First of all, if El Niño turns out to have a persistent effect on stock returns, investors might anticipate on upcoming El Niño events. Since the NOAA climate predicting center is continuously busy predicting cycles investors might follow these forecasts and earn higher than normal returns. Secondly, although there has been done a vast amount of analyes on different climatological phenomena affecting stock markets, there has not been done much research of the interrelation between El Niño and stock returns. Lastly, El Niño cycles will tend to occur more often in the future due to ongoing global warming.

Literature of El Niño on economies worldwide mainly consists of the studies of Brunner (2002) and Cashin et al. (2015). Brunner (2002) finds that ENSO cycles indeed have a statistically and economic significant effect on world commodity prices. ENSO cycles turn out to be responsible for about 20% of the commodity price movements during the 1963-1997 period. Prices also inflate with 3.5% when El Niño severity changes one standard deviation. Later on, thses results are weakened by Cashin et al. (2015), who state that the countries used in Brunner's research are not directly affected by El Niño. They overcome this problem by incorporating Asian and Australian countries in their research. Their findings are that countries on the west-coast of Asia face a shortfall in economic activity in the aftermath of El Niño, as do countries on the east-coast of South-America. The United States and the European region however, faces growth-enhancing effects after a cycle.

This research uses time-series and cross-section analyses to investigate explicitly the effect on stock market returns. Multivariate Ordinary Least Squares regressions and z-tests on the difference of means must lead to results when using the Southern Oscillation Index (SOI) and the Sea Surface Temperature (SST) as proxies for El Niño activity.

When only looking at the effect of El Niño on the moment of impact shows little statiscal significance. Only the Peruvian index is positivily affected when using SOI as only independent variable. When also incorporating the 3-, 6-, 9- and 12-months lagged effect of El Niño on stock markets the NIKKEI225 (Japan), the KSI (Korea), the IDX Composite (Indonesia) and the S&P/BVL (Peru) show statiscally negative coefficients when using SOI which indicates a positive effect on stock market returns. When using SST as independent variable, the statiscal significance is less present. Only Japan and Indonesia are positively affected by an aftermath of El Niño. After incorporating the

GDP, the 1-month rent, CPI, Import, Export and a dummy variable for the month January, El Niño's effect on the returns of the different indices remains the same. Even after including the 1-month lagged return, the results are not altered. The magnitude and t-values change slightly, but the statisical significance stays the same. It is also evident that SOI has a more predictable value than SST.

Dividing the sample in three different periods, shows that during the 1950-1970 period, the returns on the NYSE are not at all affected by El Niño. This is as expected when looking at Figure 1A and 1B. Contradictory to the expectations is however, that during the 2000-2015 subsample also no statiscal effect is found. Since the increasing problem of global warming strengthens the severity of an El Niño, an effect on stock market returns should be expected. However, the middle subsample of 1970-2000 shows a significant effect on almost every index. The only difference when using either SOI or SST as a proxy for El Niño is that the effect occurs in a earlier stadium (after 6 months) when using SOI compared to using SST (effect after 9 months). The sign and magnitude are approximately the same (see Table 10 and Table E1).

When looking at the difference in effect on stock markets between months of the most severe El Niño strikes and months where El Niño is relatively mild shows that there is no overall correlation between returns on the different stock indices and the severity of El Niño (e.g. returns are negatively affected for an increase in El Niño strength). This is based on the results of the z-test on the difference of the means. Only the SOI is used as independent variable in the cross-section analysis since the time-series analysis showed that using this variable is more efficient. When looking at how stock markets are affected in months that El Niño is more severe compared to milder El Niño months, it is found that returns are indeed more affected during the 15% heaviest months. The magnitude varies per stock index but a fact is that European countries experience positive effects from an El Niño on impact and in the aftermath. On the other hand, the South-East Asian countries who lay closer to the epicenter of El Niño, are affected in a negative manner. During and after milder El Niño periods, only the Korean KSI and American NYSE are affected at a certain point in time.

With the knowledge from the section Results it is made possible to give an answer to the stated research question. The El Niño cycle certainly affects the returns of the different stock indices. Mainly the South-East Asian indices (Japan, Korea, Indonesia) and Peruvian index are affected positively by an El Niño cycle. This effect does not so much occur on the moment of impact (except for Peru), but more in the months after a strike. This is obvious because the effects of a climatological phenomenon have to process before stock market returns will be affected. This analysis has also shown that the use of SOI as a predictor yields more significant results, which is in line with Brunner (2002). He states that the use of SOI in combination with economic data is preferred. When looking at the magnitude of the effect across the different indices, there is not a clear line to be drawn.

Concerning the Asian countries in this research the magnitude varies from 0.81% till 1.37% positive for a one unit increase in SOI value. Peru is affected both on impact and 9 months after the initial cycle, cumulating the effect to 3.07% for a one unit increase in SOI value. This result is not exactly in line with the literature because Peru and its economy is known to be affected negatively by an El Niño. When looking at the effect if SST is used, Korea's KSI is net positively affected with 0.70% for a one unit increase in sea surface temperature and Indonesia's index is positively affected with 4.71% 6 months after a cycle. The larger magnitude when using SST comes from the fact that the sea surface temperature shows less heavy shocks in its value compared to the SOI predictor.

Concluding, there is no overall evidence for the effect of El Niño on stock markets worldwide, but there are certainly several index returns that are statiscally and economically affected by a strike of El Niño.

6.1 Shortcomings & future research

Similar to previous research, this thesis also has its limitations which might be taken into account in further research. A first important consideration that had to be made during this study concerns the data on control variables. Datastream did not generate as much data as needed. A possible solution would be filling the data with the mean of the sample, but the literature stated that biased results would have been likely. However, a consequence is that values were missing which leads to less observations in the regression.

A second shortcoming of this analysis concerns the absence of a climatological control variable. Since several weather phenomena have show to have a significant impact on stock market returns, incorporating a climatological variable such as the temperature, cloudiness or percentage of precipitation might alter the results of this study. Since obtaining this data was very expensive such a variable has been omitted. An opportunity for further research might be incorporating a climatological control variable.

A last idea for further research is to investigate the effect of El Niño on the stock returns of specific sectors. Since typhoons create a lot of damage and crops grow harder or are destroyed due to El Niño, it might be interesting to test the effect on returns of for example the agricultural sector or the constructing company sector.

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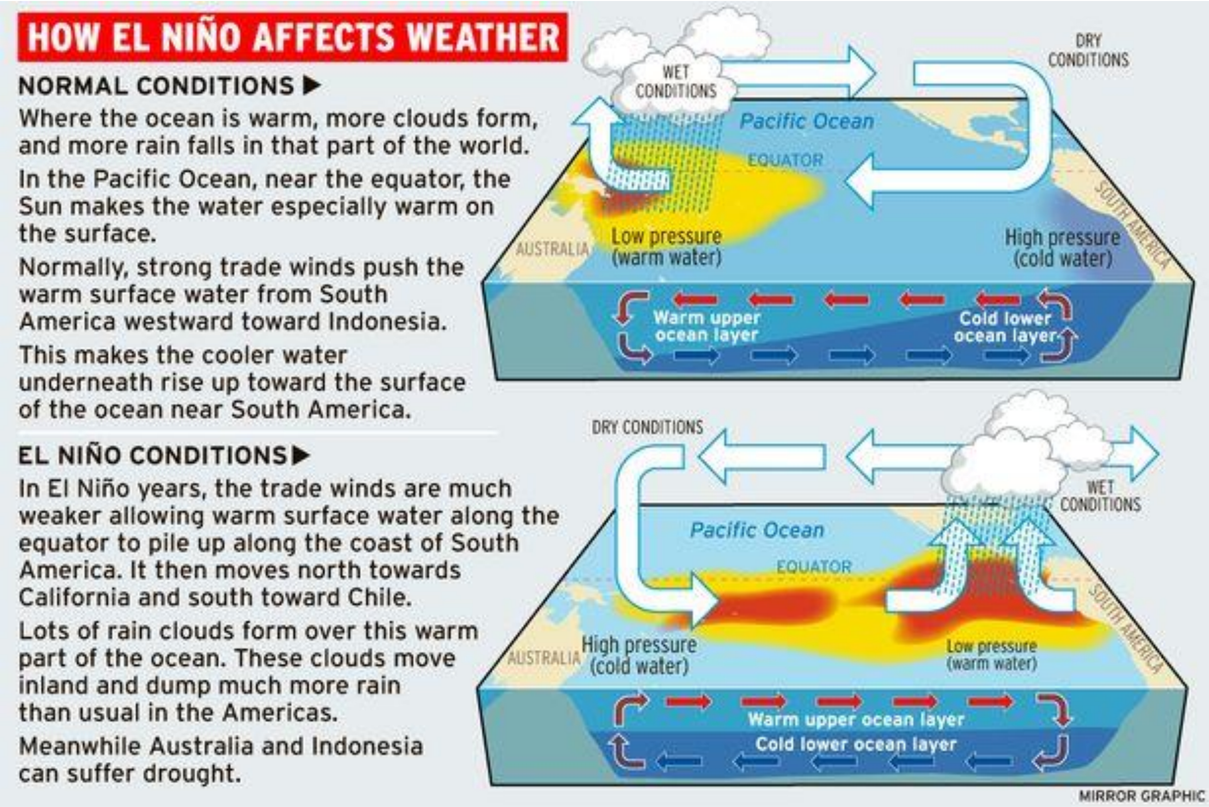
Appendix A: El Niño cycle explained

Figure A1: El Niño cycle explained graphically

Figure A1 shows in the first panel, the weather and sea conditions when no El Niño is present. The second panel shows the situation in presence of an El Niño strike. As can be seen, El Niño leads to no rainfall in the Oceania continent, whereas it brings rainy periods to South- and Middle-America. This leads to distorted climates.



Source: news article in The Mirror
http://www.mirror.co.uk/news/uk-news/uk-weather-britain-faces-snowstorms-5748324.

Appendix B: Exchange rates

In order to give more comparable descriptive statistics on the used control variables, all values are transformed to one currency which is the US Dollar ($). In this process there is made use of the current exchange rate between the US Dollar and the currency in question. Table B1 below shows an overview of the used currencies.

Table B1: Exchange rates

Table B1 shows the exchange rates between the currencies of the countries involved in this research and the US Dollar Currency. The Table should be read in the following manner: 1 Canadian Dollar is equivalent to 0.770651 US Dollar etc.

	US Dollar
Canadian Dollar	0.770651
Euro	1.127389
British Pound	1.458912
Norwegian Krone	0.121150
Japanese Yen	0.009127
Korean Won	0.000844
Peruvian Sol	0.301568
Indonesian Rupiah	0.000075

Source: http://www.x-rates.com/

Appendix C: Descriptive statistics after mean imputation

This Appendix contains the descriptive statistics of the control variableswhen complementing the missing values with the mean imputation method.

Table C1: Descriptive statistics of control variables after mean imputation

Table C1 shows the descriptive statistics of the control variables after filling missing data points with the mean of the sample per country. The GDP is presented in millions of dollars ($), the 1-month rent rate is presented in percentages, the level of inflation is presented through the countries' CPI-index and the total level of monthly import and export are presented in millions of dollars ($).

		USA	Canada	Netherlands	Germany	UK	Norway	Japan	Korea	Peru	Indonesia
GDP	*Mean*	$7,969,792	$954,599	$165,297	$674,657	$425,729	$67,297	$4,015,880	$140,948	$21,293	$143,250
	Median	$6,635,700	$953,354	$164,803	$672,978	$398,249	$67,234	$4,034,134	$131,664	$18,370	$142,500
	Maximum	$16,414,000	$1,366,492	$183,564	$785,080	$654,501	$98,058	$4,882,945	$310,592	$36,869	$173,250
	Minimum	$2,084,600	$586,005	$128,523	$572,511	$234,487	$36,910	$2,409,528	$21,732	$10,944	$123,000
	St. Dev.	$4,382,739	$208,110	$12,159	$46,596	$129,032	$17,034	$635,969	$90,308	$7,578	$6,087
	Obs	*789*	*549*	*392*	*549*	*549*	*548*	*549*	*488*	*295*	*388*
Rent	*Mean*	5.54%	6.33%	3.95%	4.35%	6.25%	3.74%	2.70%	2.84%	7.38%	12.99%
	Median	5.53%	6.33%	3.69%	4.34%	6.24%	3.73%	2.70%	2.84%	1.50%	12.98%
	Maximum	19.38%	22.06%	9.81%	14.00%	15.19%	8.49%	14.44%	5.33%	58.30%	71.00%
	Minimum	0.09%	0.23%	-0.15%	-0.15%	0.46%	1.10%	-0.50%	-14.40%	0.46%	3.98%
	St. Dev.	3.19%	4.09%	2.59%	2.66%	3.46%	1.37%	2.85%	1.22%	10.87%	8.95%
	Obs	*789*	*549*	*392*	*549*	*549*	*548*	*549*	*488*	*295*	*388*
CPI	*Mean*	105.2	76.9	87.3	73.1	75.5	81.4	86.9	60.4	81.2	67.7
	Median	97.9	84.7	85.4	75.2	75.6	89.3	99.4	60.1	84.2	67.9
	Maximum	238.1	127.3	117.8	107.2	100.4	140.6	104.5	110.2	120.7	121.7
	Minimum	23.5	20.2	62	32.1	48.4	17.5	31.9	9.9	12.6	19
	St. Dev.	71.5	32.7	17.1	21.7	10.7	37.8	20.7	30.2	25.2	23.1
	Obs	*789*	*549*	*392*	*549*	*549*	*548*	*549*	*488*	*295*	*388*
Import	*Mean*	$80,632	$20,910	$18,978	$52,270	$20,288	$2,320	$28,887	$14,045	$1,391	$5,075
	Median	$80,731	$20,930	$16,832	$52,270	$15,645	$1,842	$24,809	$8,333	$728	$2,821
	Maximum	$197,927	$36,015	$39,335	$91,667	$55,320	$7,795	$73,445	$45,873	$3,945	$17,417
	Minimum	$7,266	$8,181	$6,597	$22,842	$788	$217	$4,615	$473	$233	$659
	St. Dev.	$47,971	$6,137	$9,903	$14,987	$15,841	$1,686	$15,983	$13,967	$1,113	$4,802
	Obs	*789*	*549*	*392*	*549*	*549*	*548*	*549*	*488*	*295*	*388*
Export	*Mean*	$587,737	$270,332	$20,939	$44,113	$74,857	$3,546	$32,820	$14,871	$1,533	$6,252
	Median	$293,200	$270,332	$18,040	$32,390	$57,195	$2,308	$32,248	$9,350	$768	$4,546
	Maximum	$2,360,600	$491,278	$43,664	$114,892	$193,694	$11,047	$70,111	$51,631	$4,555	$18,648
	Minimum	$11,700	$72,370	$6,641	$5,535	$4,065	$142	$3,587	$287	$240	$1,021
	St. Dev.	$680,849	$118,318	$11,351	$31,617	$58,124	$3,124	$15,564	$15,191	$1,277	$4,795
	Obs	*789*	*549*	*392*	*549*	*549*	*548*	*549*	*488*	*295*	*388*

Appendix D: Correlation matrices of control variables

Table D1: Correlation matrices of control variables

Table D1 shows the correlation between the different control variables per country. Not that one Table shows correlions from two countries, above and below the diagonal axis.

USA (above diagonal) / **CAN** (below diagonal)

	GDP	*Rent*	*CPI*	*Import*	*Export*
GDP	1	-0.77	0.99	0.96	0.95
Rent	-0.84	1	-0.76	-0.73	-0.74
CPI	0.98	-0.79	1	0.94	0.95
Import	0.98	-0.82	0.96	1	0.99
Export	0.97	-0.84	0.95	0.98	1

NL (above diagonal) / **GER** (below diagonal)

	GDP	*Rent*	*CPI*	*Import*	*Export*
GDP	1	-0.48	0.93	0.91	0.91
Rent	-0.79	1	-0.83	-0.79	-0.79
CPI	0.98	-0.63	1	0.97	0.97
Import	0.97	-0.73	0.96	1	1.00
Export	0.99	-0.76	0.97	0.99	1

UK (above diagonal) / **NOR** (below diagonal)

	GDP	*Rent*	*CPI*	*Import*	*Export*
GDP	1	-0.85	0.94	0.98	0.98
Rent	-0.66	1	-0.89	-0.86	-0.88
CPI	0.97	-0.67	1	0.97	0.98
Import	0.95	-0.57	0.92	1	0.98
Export	0.95	-0.53	0.90	0.97	1

KOR (above diagonal) / **JPN** (below diagonal)

	GDP	*Rent*	*CPI*	*Import*	*Export*
GDP	1	-0.44	0.99	0.94	0.95
Rent	-0.87	1	-0.48	-0.35	-0.38
CPI	0.93	-0.73	1	0.91	0.92
Import	0.71	-0.57	0.69	1	0.99
Export	0.80	-0.65	0.82	0.94	1

PER (above diagonal) / **IND** (below diagonal)

	GDP	*Rent*	*CPI*	*Import*	*Export*
GDP	1	-0.63	0.89	0.96	0.95
Rent	0.23	1	-0.87	-0.52	-0.56
CPI	0.97	-0.55	1	0.79	0.80
Import	0.20	-0.50	0.88	1	0.96
Export	-0.16	-0.53	0.90	0.97	1

Appendix E: Multivariate regressions SST

Table E1: Multivariate regression with SST after adding control variables

Table E1 shows the results of the multivariate regression per country for the full sample period. The dependent variable is the return of the index as stated in Regression 3. The independent variables are the Sea Surface Temperature (SST) on impact and the same variable with a lag of 3, 6, 9 and 12 months. GDP represents the monthly GDP in millions for each country in its own currency, R is the 1-month interest rate, CPI is a monthly index number, import and export are depicted monthly in millions[22] and D_{jan} is a dummy variable that equals 1 in the month January and 0 otherwise. The numbers in parentheses represent the p-values of the coefficients.

	USA	*Canada*	*Netherlands*	*Germany*	*UK*	*Norway*	*Japan*	*Korea*	*Peru*	*Indonesia*
C	0.0172	0.0385	0.2440**	0.7780***	0.1217*	0.0838	0.2413**	0.0158	-0.0921	0.0199
	(0.4411)	(0.4820)	(0.0292)	(0.0040)	(0.0900)	(0.5322)	(0.0198)	(0.1985)	(0.3059)	(0.4405)
SST	0.0005	0.0025	0.0043	0.0012	0.0049	-0.0007	-0.0071	-0.0174*	-0.0243	-0.0131
	(0.9356)	(0.7282)	(0.7285)	(0.9071)	(0.4887)	(0.9614)	(0.4037)	(0.0810)	(0.1766)	(0.4411)
SST_{t-3}	-0.0008	-0.0102	-0.0226	-0.0142	-0.0084	-0.0356**	-0.0052	-0.0102	-0.0127	-0.0140
	(0.8969)	(0.1870)	(0.1030)	(0.1934)	(0.2724)	(0.0208)	(0.5866)	(0.3520)	(0.5410)	(0.4655)
SST_{t-6}	-0.0016	0.0046	0.0118	0.0078	0.0114	0.0075	0.0019	0.0244**	0.0183	0.0471**
	(0.7984)	(0.5510)	(0.3990)	(0.4770)	(0.1362)	(0.6300)	(0.8467)	(0.0276)	(0.3342)	(0.0170)
SST_{t-9}	-0.0058	-0.0019	0.0058	0.0049	0.0006	0.0057	0.0064	-0.0061	0.0020	-0.0188
	(0.3725)	(0.8101)	(0.6819)	(0.6596)	(0.9357)	(0.7204)	(0.5167)	(0.5869)	(0.9164)	(0.3505)
SST_{t-12}	0.0054	0.0021	-0.0146	-0.0092	-0.0018	-0.0096	0.0100	0.0127	-0.0137	0.0298
	(0.3561)	(0.7736)	(0.2431)	(0.3783)	(0.8006)	(0.5063)	(0.2655)	(0.2121)	(0.4516)	(0.1055)
GDP	4.9E-10	1.1E-07	7.8E-07	-1.2E-06**	-1.2E-07	1.9E-07	2.9E-11	9.72E-11	3.1E-06*	
	(0.9284)	(0.1488)	(0.5107)	(0.0138)	(0.4097)	(0.5733)	(0.8666)	(0.7553)	(0.0760)	
R	-0.0006	-0.0043**	-0.0190**	-0.0092	-0.0021	-0.0116***	-0.0045**		0.0033*	-0.0014**
	(0.4240)	(0.0105)	(0.0019)	(0.3783)	(0.1521)	(0.0001)	(0.0198)		(0.0531)	(0.0441)
CPI	-8.4E-06	-0.0008	-0.0031	-0.0018	-0.0014	-0.0007	-0.0023	-0.0003	-0.0006	0.0001
	(0.9759)	(0.4682)	(0.1875)	(0.4728)	(0.2459)	(0.6457)	(0.1353)	(0.7704)	(0.7287)	(0.7177)
IMPORT	-4.2E-06	-3.2E-06	-0.0031	-8.9E-07	-2.8E-06	-1.7E-06	2.8E-09	-7E-06***	-0.0001***	-6.27E-06
	(0.1581)	(0.1133)	(0.1875)	(0.4770)	(0.4407)	(0.1618)	(0.6189)	(0.0043)	(0.0002)	(0.2102)
EXPORT	2.8E-06	2.7E-06	3.8E-06	3.5E-06**	1.2E-06	-5.3E-07	-5.8E-09	6.1E-06**	4.8E-05	4.21E-06
	(0.2127)	(0.8021)	(0.6001)	(0.0278)	(0.2873)	(0.4773)	(0.4081)	(0.0102)	(0.0089)	(0.4951)
D_{jan}	0.0002	0.0149	0.0281**	0.0147	0.0193**	0.0243	0.0042	0.0157	0.0492**	0.0320
	(0.9764)	(0.0876)	(0.0510)	(0.2494)	(0.0272)	(0.1578)	(0.7118)	(0.2132)	(0.0364)	(0.1151)
R^2	0.0176	0.0527	0.1092	0.0613	0.0460	0.1284	0.0422	0.0451	0.1261	0.0732

***, ** and * indicate significance at the 1%-, 5%- and 10%-confidence level, respectively.

[22] Each country has the variables Imports and Exports depicted in its own currency, except for Peru and Indonesia which are stated in millions of dollars ($).

Table E2: Multivariate regression with SST after adding 1-month lagged return

Table E2 shows the results of the multivariate regression per country for the full sample period. The dependent variable is the return of the index as stated in Regression 3. The independent variables are the Sea Surface Temperature (SST) on impact and the same variable with a lag of 3, 6, 9 and 12 months. GDP represents the monthly GDP in millions for each country in its own currency, R is the 1-month interest rate, CPI is a monthly index number, import and export are depicted monthly in millions[23], D_{jan} is a dummy variable that equals 1 in the month January and 0 otherwise and R_{t-1} is the1-month lagged return on the index. The numbers in parentheses represent the p-values of the coefficients.

	USA	*Canada*	*Netherlands*	*Germany*	*UK*	*Norway*	*Japan*	*Korea*	*Peru*	*Indonesia*
C	0.0151	0.0379	0.2636**	0.7752***	0.1226*	0.0845	0.2350**	0.0194	-0.0920	0.0174
	(0.5025)	(0.4886)	(0.0221)	(0.0047)	(0.0890)	(0.5314)	(0.0241)	(0.3363)	(0.3072)	(0.4999)
SST	0.0003	0.0021	0.0049	0.0011	0.0050	-0.0006	-0.0070	-0.0174*	-0.0243	-0.0119
	(0.9524)	(0.7752)	(0.6898)	(0.9096)	(0.4815)	(0.9634)	(0.4105)	(0.0810)	(0.1781)	(0.4830)
SST_{t-3}	-0.0004	-0.0099	-0.0228	-0.0142	-0.0085	-0.0360**	-0.0053	-0.0090	-0.0117	-0.0158
	(0.9460)	(0.1978)	(0.0997)	(0.1956)	(0.2696)	(0.0211)	(0.5798)	(0.4118)	(0.5425)	(0.4117)
SST_{t-6}	-0.0020	0.0045	0.0121	0.0077	0.0115	0.0075	0.0020	0.0230**	0.0183	0.0456**
	(0.7494)	(0.5596)	(0.3878)	(0.4821)	(0.1349)	(0.6307)	(0.8365)	(0.0376)	(0.3353)	(0.0207)
SST_{t-9}	-0.0052	-0.0019	0.0059	0.0049	0.0007	0.0057	0.0062	-0.0057	0.0020	-0.0182
	(0.4201)	(0.8053)	(0.6765)	(0.6609)	(0.9271)	(0.7193)	(0.5251)	(0.5869)	(0.9172)	(0.3658)
SST_{t-12}	0.0052	0.0017	-0.0145	-0.0092	-0.0019	-0.0096	0.0096	0.0118	-0.0137	0.0257
	(0.3759)	(0.8147)	(0.2459)	(0.3799)	(0.7978)	(0.5089)	(0.2819)	(0.2457)	(0.4528)	(0.1655)
GDP	6.8E-10	1.0E-07	8.1E-07	-1E-06**	-1.2E-07	1.9E-07	2.8E-11	4.56E-11	3.1E-06*	
	(0.9010)	(0.1650)	(0.4932)	(0.0152)	(0.4056)	(0.5739)	(0.8706)	(0.8837)	(0.0781)	
R	-0.0006	-0.004**	-0.0199***	-0.001***	-0.0021	-0.011***	-0.004**		0.0033*	-0.0012*
	(0.4741)	(0.0148)	(0.0015)	(0.0078)	(0.1512)	(0.0001)	(0.0235)		(0.0547)	(0.0782)
CPI	-1.3E-05	-0.0008	-0.0034	-0.0018	-0.0014	-0.0007	-0.0023	-7.48E-05	-0.0006	0.0002
	(0.9630)	(0.4746)	(0.1574)	(0.4760)	(0.2439)	(0.6446)	(0.1479)	(0.9328)	(0.7296)	(0.7351)
IMPORT	-4.1E-07	-3.0E-06	3.6E-06	-8.9E-07	-2.8E-06	-1.7E-06	2.8E-09	-7E-06***	-1E-04***	-5.79E-06
	(0.1650)	(0.1416)	(0.6153)	(0.4788)	(0.4378)	(0.1625)	(0.6203)	(0.0074)	(0.0003)	(0.2478)
EXPORT	2.8E-08	2.1E-08	-3.1E-06	4E-06***	1.3E-06	-5.3E-07	-5.8E-09	5.7E-06**	5E-06**	3.92E-06
	(0.2234)	(0.8428)	(0.6526)	(0.0298)	(0.2844)	(0.4803)	(0.4101)	(0.0157)	(0.0105)	(0.5251)
Djan	-0.0003	0.0151*	0.0284**	0.0146	0.0193**	0.0242	0.0041	0.0150	0.0492**	0.0311
	(0.9670)	(0.0823)	(0.0490)	(0.2544)	(0.0279)	(0.1607)	(0.7243)	(0.2329)	(0.0367)	(0.1254)
R_{t-1}	0.0535	0.0693	-0.0500	0.0038	-0.0094	-0.0040	0.0282	0.0590	0.0007	0.0915
	(0.2422)	(0.2100)	(0.4548)	(0.9492)	(0.8647)	(0.9531)	(0.5644)	(0.1970)	(0.9905)	(0.1723)
R^2	0.0204	0.0574	0.1114	0.0613	0.0460	0.1284	0.0430	0.0485	0.1261	0.0809

***, ** and * indicate significance at the 1%-, 5%- and 10%-confidence level, respectively.

[23] Each country has the variables Imports and Exports depicted in its own currency, except for Peru and Indonesia which are stated in millions of dollars ($).

Appendix F: Multvariate regressions SST subsamples

Table F1: Multivariate regression of 1970-2000 subsample

Table F1 shows the results of the multivariate regression for the 1970-2000 period. The dependent variable is the return of the index as stated in Regression 3. The independent variables are the Sea Surface Temperature (SST) on impact and the same variable with a lag of 3, 6, 9 and 12 months. GDP represents the monthly GDP in its own currency, R is the 1-month interest rate, CPI is a monthly index number, import and export are depicted monthly in millions and D_{jan} is a dummy variable that equals 1 in the month January and 0 otherwise. The numbers in parentheses represent the p-values of the coefficients.

	USA	*Canada*	*Netherlands*	*Germany*	*UK*	*Norway*	*Japan*	*Korea*	*Peru*	*Indonesia*
C	0.0818	-0.0371	0.0514	0.1394	0.0738	-0.0411	0.0666	0.0022	-0.5941	0.0213
	(0.1994)	(0.9051)	(0.5434)	(0.8267)	(0.5986)	(0.4638)	(0.6675)	(0.8971)	(0.0716)	(0.3447)
SST	-0.0026	0.0009	-0.0079	0.0022	0.0075	-0.0031	-0.0199*	-0.0155	-0.0811**	-0.0288
	(0.7209)	(0.9294)	(0.5078)	(0.8831)	(0.4713)	(0.8174)	(0.0729)	(0.2302)	(0.0358)	(0.2016)
SST_{t-3}	0.0011	-0.0081	-0.0034	-0.0191	-0.0071	-0.0162	-0.0099	-0.0174	-0.0350	0.0219
	(0.8842)	(0.4272)	(0.7961)	(0.2004)	(0.5122)	(0.2845)	(0.4252)	(0.2247)	(0.3306)	(0.3844)
SST_{t-6}	-0.0002	0.0054	0.0157	-0.0023	0.0158	0.0176	0.0096	0.0298**	0.0437	0.0202
	(0.9795)	(0.5932)	(0.2229)	(0.8788)	(0.1440)	(0.2447)	(0.4367)	(0.0371)	(0.2170)	(0.4165)
SST_{t-9}	-0.0173**	-0.0132	-0.0213*	-0.0088	-0.0128	-0.0299**	-0.0089	-0.0198	-0.0381	-0.0659***
	(0.0272)	(0.1990)	(0.0949)	(0.5637)	(0.2411)	(0.0461)	(0.4706)	(0.1635)	(0.2753)	(0.0077)
SST_{t-12}	0.0061	0.0039	0.0070	-0.0200	-0.0037	0.0115	0.0132	0.0156	-0.0269	0.0644***
	(0.3919)	(0.6878)	(0.5433)	(0.1595)	(0.7281)	(0.3797)	(0.2358)	(0.2296)	(0.4517)	(0.0030)
GDP	-1.47E-08	2.37E-07		-1.54E-06	1.63E-07	2.89E-07	-3.22E-10	1.13E-09	1.74E-05*	
	(0.3031)	(0.4859)		(0.2969)	(0.8121)	(0.2573)	(0.2171)	(0.1117)	(0.0846)	
R	-0.0011	-0.0048**	-0.0044*	0.0049	-0.0028		-0.0042*		0.0062*	
	(0.2414)	(0.0466)	(0.0873)	(0.5914)	(0.2070)		(0.0583)		(0.0518)	
CPI	0.0003	-0.0012	3.26E-05	0.0070	-0.0015	4.58E-05	0.0019	-0.0007	-0.0023	
	(0.4205)	(0.4143)	(0.9843)	(0.2856)	(0.4102)	(0.9439)	(0.4835)	(0.5508)	(0.5265)	
IMPORT	5.41E-07	-6.03E-06	-6.37E-06	-5.52E-07	3.87E-06	-3.72E-06	-1.05E-08	-1.45E-05	-0.0001	6.62E-06
	(0.6275)	(0.4177)	(0.5988)	(0.8830)	(0.7343)	(0.2472)	(0.3878)	(0.0046)	(0.6369)	(0.7129)
EXPORT	2.26E-08	1.36E-07	4.59E-06	4.32E-06	-8.36E-07	-1.54E-06	-1.87E-08	1.28E-06	-0.0002	-1.09E-05
	(0.7026)	(0.7358)	(0.6941)	(0.3539)	(0.7737)	(0.4983)	(0.2130)	(0.8586)	(0.4528)	(0.4553)
D_{jan}	0.0116	0.0111	0.0286*	0.0049	0.0220	0.0003	-0.0137	0.0043	0.0960*	0.0733**
	(0.2034)	(0.3730)	(0.0658)	(0.8028)	(0.1094)	(0.9848)	(0.3994)	(0.8096)	(0.0737)	(0.0130)
R^2	0.0336	0.0630	0.0534	0.0659	0.0594	0.0344	0.0922	0.0649	0.2420	0.0949

***, ** and * indicate significance at the 1%-, 5%- and 10%-confidence level, respectively.

Table F2: Multivariate regression of 2000-2015 subsample

Table F2 shows the results of the multivariate regression for the 2000-2015 period. The dependent variable is the return of the index as stated in Regression 3. The independent variables are the Sea Surface temperature (SST) on impact and the same variable with a lag of 3, 6, 9 and 12 months. GDP represents the monthly GDP in its own currency, R is the 1-month interest rate, CPI is a monthly index number, import and export are depicted monthly in millions and D_{jan} is a dummy variable that equals 1 in the month January and 0 otherwise. D_{crisis} is a dummy variable that equals one in the years 2007-2009 and zero otherwise The numbers in parentheses represent the p-values of the coefficients.

	USA	Canada	Netherlands	Germany	UK	Norway	Japan	Korea	Peru	Indonesia
C	-0.1105	-0.2157	0.1658	0.9103**	0.0652	0.3743*	0.6627	-0.0715	-0.0834	0.0289
	(0.4854)	(0.0935)	(0.5027)	(0.0228)	(0.5706)	(0.0560)	(0.2903)	(0.6651)	(0.6667)	(0.5100)
SST	0.0014	0.0093	-0.0045	-0.0177	-0.0043	0.0031	-0.0099	-0.0259*	-0.0072	-0.0169
	(0.8918)	(0.3841)	(0.7470)	(0.2310)	(0.6825)	(0.8361)	(0.4685)	(0.0992)	(0.7286)	(0.3012)
SST_{t-3}	-0.0030	-0.0138	-0.0186	-0.0136	-0.0136	-0.0183	0.0012	0.0013	0.0037	-0.0072
	(0.7886)	(0.2342)	(0.2159)	(0.3902)	(0.2244)	(0.2562)	(0.9343)	(0.9338)	(0.8670)	(0.6709)
SST_{t-6}	-0.0068	0.0024	0.0043	0.0057	0.0006	0.0081	-0.0109	0.0091	-0.0127	0.0177
	(0.5482)	(0.8382)	(0.7809)	(0.7230)	(0.9593)	(0.6239)	(0.4593)	(0.5760)	(0.5678)	(0.3028)
SST_{t-9}	0.0185	0.0064	0.0125	0.0066	0.0100	0.0149	0.0270*	0.0174	0.0248	-0.0040
	(0.1106)	(0.6091)	(0.4435)	(0.6977)	(0.3930)	(0.3802)	(0.0859)	(0.3048)	(0.2836)	(0.8240)
SST_{t-12}	0.0065	-0.0062	-0.0133	-0.0077	-0.0092	-0.0166	-0.0113	-0.0041	-0.0120	0.0023
	(0.5630)	(0.5954)	(0.3894)	(0.6315)	(0.4170)	(0.3078)	(0.4443)	(0.8014)	(0.5875)	(0.8942)
GDP	2.44E-08	1.46E-07	1.71E-06	2.52E-08	7.3E-07**	-3.25E-07	-5.84E-10	-8.85E-10	-7.49E-07	
	(0.1390)	(0.5478)	(0.4426)	(0.9775)	(0.0337)	(0.4406)	(0.4440)	(0.3859)	(0.7462)	
R	-0.0010	0.0033	-0.0220***	-0.0304***	-0.0107***	-0.0160***	-0.1073***	0.0044	-0.0096**	-0.0049**
	(0.7444)	(0.4923)	(0.0021)	(0.0033)	(0.0043)	(0.0002)	(0.0000)	(0.1733)	(0.0372)	(0.0323)
CPI	-0.0009	0.0022	-0.0035	-0.0111**	-0.0039*	-0.0005	-0.0046	0.0035	0.0024	0.0006
	(0.5588)	(0.5483)	(0.1871)	(0.0399)	(0.0583)	(0.7550)	(0.2640)	(0.4158)	(0.4980)	(0.2528)
IMPORT	-7.8E-07*	-8.2E-06**	2.39E-06	-1.22E-06	-3.96E-06	-5.76E-07	1.05E-08	-7E-06***	-6.7E-05**	-1E-05***
	(0.0809)	(0.0192)	(0.7548)	(0.4247)	(0.3507)	(0.6701)	(0.3359)	(0.0099)	(0.0302)	(0.0070)
EXPORT	4.36E-08	5.40E-08	-2.97E-06	3.8E-06**	1.12E-06	-4.71E-08	1.00E-08	6.72E-06*	3.40E-05*	9.63E-06*
	(0.3861)	(0.8117)	(0.6728)	(0.0496)	(0.4052)	(0.9521)	(0.2888)	(0.0540)	(0.0681)	(0.0686)
D_{jan}	-0.0141	0.0123	0.0217	0.0124	0.0160	0.0245	0.0323*	0.0240	0.0131	0.0284
	(0.2362)	(0.3358)	(0.1825)	(0.4742)	(0.1824)	(0.1778)	(0.0733)	(0.2226)	(0.6055)	(0.1202)
D_{crisis}	-0.0069	-0.0199*	0.0081	0.0400**	-0.0047	0.0175	0.0258	0.0129	-0.0077	-0.0079
	(0.5060)	(0.0677)	(0.6575)	(0.0413)	(0.6119)	(0.2395)	(0.1022)	(0.3488)	(0.6422)	(0.5419)
R^2	0.0629	0.0947	0.1085	0.1128	0.0901	0.1460	0.1569	0.0928	0.1116	0.0904