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The influence of the El Niño proxy – the ‘Southern Oscillation Index’- on food commodity prices

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Abstract: This thesis investigates the effect of the El Niño proxy – the ‘Southern Oscillation Index’- on the prices of selected food commodities for a time span of 1980 until 2016, quoted in monthly prices. The selected commodities were Cocoa, Coffee, Rice, Peruvian Fish, Palm oil and Soybeans. For two commodities – Palm oil and Peruvian fish- a significant impact was found with a price increase of around 0.7% up to three months after a one unit increase in the Southern Oscillation Index. For the other commodities, no significant influence was found. The first hypothesis investigated in this thesis, has shown that there are no nonlinear effects visible. The second hypothesis does show, however, that a time varying effect exists, with the impact of El Niño on the commodity prices getting smaller as we move up in time. The reason behind this phenomenon is not examined in this thesis.

Keywords: ENSO, El Niño, SOI, commodity prices

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Introduction

Last year was a year when one of the heaviest El Niño episodes in decades took place. The consequences were all over the news. From bushfires due to extreme draught in Australia and Indonesia, to floods due to extreme precipitation in Peru and other South-American countries. Besides that, some parts of Africa were hit by famine. All these effects were (indirectly) caused by the changing weather conditions during an El Niño episode. El Niño not only drew attention of the world news, financial newspapers also stood full with headlines about this phenomenon. Some of those headlines were "Palm oil facing 'powerful cocktail of El Niño, Fuel demand" (Bloomberg) and "Commodity Prices rising in wait of El Niño" (Financieel dagblad). So, anecdotic evidence enough that El Niño has enormous impact on everyday life in large parts of the world. However, do those anecdotic stories works its way through in real numbers? This question will be answered in this thesis. The main question in this thesis therefore is:

"What is the impact of the El Niño proxy – the 'Southern Oscillation Index'- on food commodity prices."

Earlier research has shown that El Niño has consequences for the price of both non-fuel commodities and fuel commodities (Brunner, 2002; Cashin et al. 2014). Also other researches has focussed on the effect of the El Niño Southern Oscillation (ENSO in short) on commodity prices. For example, Ubilava (2012) examined how coffee prices reacted on El Niño conditions. However, all those papers examined only or commodities as a whole (e.g. Brunner, 2002; Cashin et al., 2014), or one specific commodity (e.g. Ubilava, 2012). This paper tries therefore to complement the existing literature by examining a selected group of food commodities in one research, so that differences among the commodities can be analysed in the most optimal way.

A database has been generated with data of the El Niño proxy - the Southern Oscillation Index (SOI)- and the selected food commodities (Cocoa, Coffee, Rice, Fish, Palm oil and Soybeans). Subsequently, regressions have been run with the respective prices as dependent variable and the SOI as independent variable. Besides that, I constructed hypotheses that tested possible nonlinear effects and a time varying effect of the influence of El Niño.

The results show that some commodities do significantly react on El Niño-like circumstances. This depends mainly on the characteristics of the commodities. The common trend is a rise in the food prices of around 0.7% after one month, where after this upwards price pressure remains consistent for at least another two months. I found no suggestions for nonlinear effects. However, the results do suggest that there exists a time varying effect, although the cause of this time varying effect is not answered in this thesis. The time varying effect entails that the food commodities are more resistant to the influence of El Niño in more recent time periods.

The results contribute to the existing literature with the new insight that the influence of El Niño on the food prices is subject to change. Also, this thesis functions as a bridge between the very detailed papers that examine only one commodity and the articles that uses whole food indexes as dependent subjects. The findings of this paper need to be interpreted carefully, as the statistical methods used are by far not as advanced as the methods applied in the existing literature. However, the results can be used as a simple and clear description of the relationship between El Niño and the food prices.

This thesis is build up as follows: Section 1 starts with a literature review that consist out of an explanation of the El Niño phenomenon and the weather consequences paired with such an event. Furthermore, the literature review describes the findings of the existing literature on this specific subject; the combination of commodity prices and El Niño events. Section 2 provides the development of the hypotheses and the characteristics of the selected food commodities. In section 3 I describe the datasets that are used for this research and the first patterns that can be found in this data. Thereafter, section 4 and section 5 discuss the research methods and the results, respectively. Finally, section 6 contains the conclusion of this thesis. Robustness checks and results on control variables can be found in the appendix.

1. Literature review

This section elaborates on the existing literature concerning the subjects which are important for this paper. First, El Niño is described and the consequences of an El Niño-period for the world gets discussed. Thereafter, the two main subjects of this paper will be combined; in the latest subsection is investigated what for possible influence El Niño could have on the commodity prices, according to the existing literature.

1.1.1 What is El Niño exactly

El Niño is a world-wide known phenomenon. Its name literally means 'Christmas boy', as El Niño often made its appearance around Christmas time. However, this name was given to this phenomenon a long time ago by Peruvian fishermen, who noticed an annual weak warm water ocean that ran southwards along the South-American continent. Only subsequently, the name El Niño was given to the event as we know it nowadays; an unusual warm sea surface that only occurs one in every few years. So, only the meaning of El Niño has changed over time and not the event itself, which could lead to confusion if not stated clearly (Trenberth, 1987).

Together with the atmospheric part of El Niño - the "Southern Oscillation"- scientists and researchers often give it the name El Niño – Southern Oscillation, or just ENSO in short. An ENSO event entails that there are anomalies in the sea level surface temperature and the air pressure at the Pacific Ocean. Those anomalies arise first at the eastern part of the Pacific Ocean, near the South-American coast. At the East-Pacific there is, under normal conditions, a high air pressure. In contrary to the eastern part, the West-Pacific is normally a low-pressure area. Therefore, a strong wind blows from east to west. This wind, known as the Trade Winds, causes the warm sea surface to flow from east to west, too. Subsequently, cold water wells up from the bottom of the ocean, replacing the displaced warmer water (Wyrtki, 1985). This cold water is nutrient and with a lot of oxygen in it, making it outstanding circumstances to live in for many fish. Fishery is therefore an important industry in Peru. This cycle of water flowing from east to west is called southern oscillation. However, during an ENSO period anomalies arise, and those anomalies have consequences for the weather in a large part of the world.

When the 'normal' air pressures changes (i.e. lower pressure at the East-Pacific and higher pressure at the West- Pacific), the trade winds are not as powerful anymore and they could even turn around completely. As a consequence, the warm water surface at Peru does not get pushed towards the west anymore. The temperature of the east side of the Pacific-Ocean will rise, which leads eventually to the extreme weather conditions that we call El Niño. Those anomalies can be captured in measurable variables. Those variables are used throughout the world as proxy's for El

Niño (Trenberth, 1987). The variable that measures the deviation of the normal air pressure at the Pacific-Ocean is the Southern Oscillation Index[1] (SOI). The other proxy, the sea temperature, is called the Sea Surface Temperature[2] (SST).

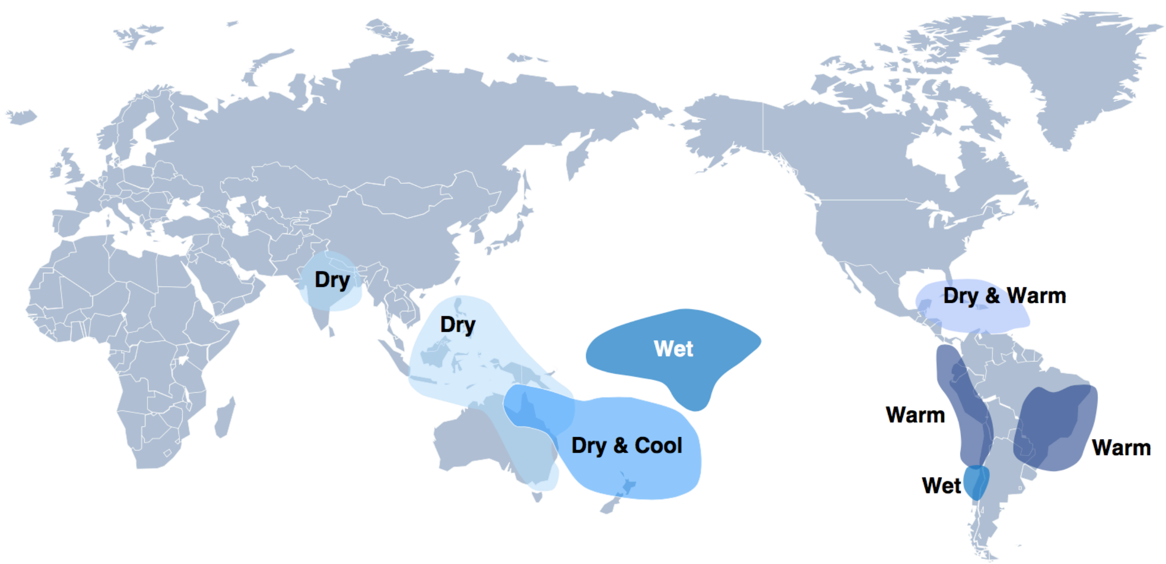
1.1.2. Weather consequences of an El Niño

El Niño has climatological consequences for a large part of the world. Its epicentre is the Pacific Ocean, so it is clear that countries lying around the Pacific experience the most extreme (weather) consequences of an El Niño. What those consequences are vary per area, but one could say that the weather conditions are the opposite from normal during an ENSO episode. So, dry regions experience much more precipitation during an ENSO period and vice versa. This can best be shown on a map (figure 1a &1b). The maps show the consequences for summer and winter periods. Obviously, the weather changes from summer to winter. Those seasonal effects also have consequences for the El Niño conditions, which change along with the seasons.

During an ENSO, precipitation increases at the west coast of South-America, in comparison to the dry conditions under the absence of an El Niño. Central America experiences much dryer periods than normal, which is the same for large parts of Australia and Indonesia. The consequences of ENSO reach much further than this. For example, in Africa it varies from north to south what the consequences are. The southern part of Africa experiences more droughts during an ENSO while parts of North-Africa faces much more precipitation than normal. The total global effects reach even further than this. For example, the dessert-like areas at the east coast of America (Florida, California) experience more precipitation during El Niño's. However, this research is mainly focussed on the Southern-Hemisphere, where most of the food commodities are produced. Therefore, consequences for other parts in the world will not be treated in this paper.

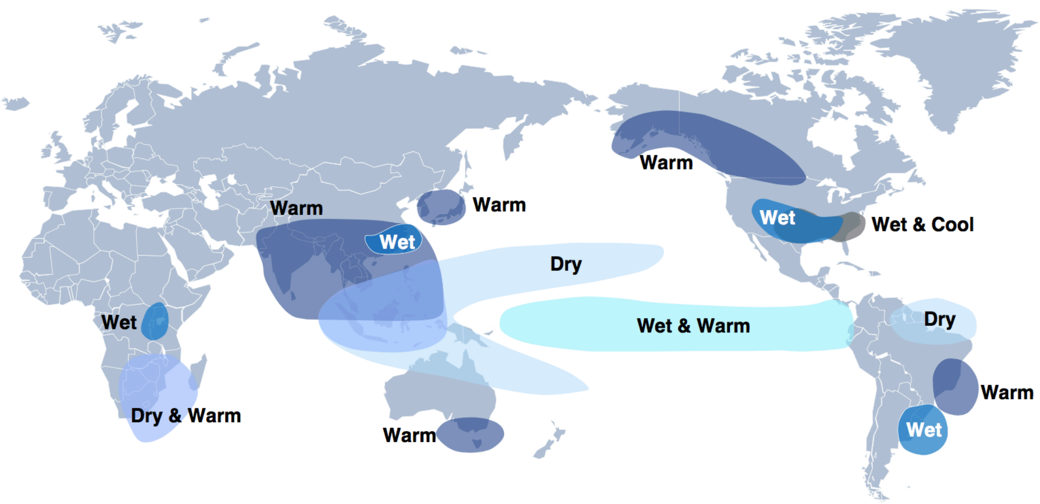
[1] The Southern Oscillation Index is explained in more detail in the section Methodology.
[2] The Sea Surface Temperature is not used in this paper, the motivation herefor can be found in the next section.

Figure 1a. Weather consequences of an El Niño during summer (Northern hemisphere calendar)



Source: "El Niño – the equity price disconnect", Barclays, 8 May 2014.

Figure 1b. Weather consequences of an El Niño during winter (Northern Hemisphere calendar)



Source: "El Niño – the equity price disconnect", Barclays, 8 May 2014.

1.2 Combining the two: El Niño and commodity prices

Looking at the completely changing ecological conditions during ENSO events, it is logical that commodities do get affected by this dramatically changing circumstances. However, it remains the question if the commodities are as such affected that also their prices react to it. There are a couple of studies who investigated the effect of an El Nino episode on worldwide commodity prices (e.g. Cashin et al., 2012, Brunner, 2002). In this section, the most important conclusions of the existing literature will be described. This section also includes some agricultural consequences of the above described weather consequences of El Niño.

Brunner (2002) used in his research to the reaction of the commodity prices both variables described in the previous section. By using the SOI and the SST[3], he was the first researcher that used continuous variables to measure the effect of El Niño on the commodity prices. He concluded that the use of the Southern Oscillation Index as a proxy for El Niño yielded the best and strongest results. Therefore, I chose the SOI to use as main variable throughout the paper. Brunner focused on his paper especially on the relation between the El Niño variables and the real non-oil commodity prices. He found that there is a strong connection between the two; a one standard deviation in the SOI leads to a rise in real commodity prices of around 3.5 percentage point. This peak is reached around two quarters after the first deviation in SOI becomes visible. However, the prices decrease to their normal value after 2 to 3 years. This price effect is strongest for food commodities, although beverages and agricultural raw-materials also experience an influence of ENSO. He also researched the effect of El Niño on the world-wide economy and some other economic variables like, inflation. The relationships between the other economic variables were less strong than the effect on the commodity prices, however, there still was some connection between them.

Ubilava (2012) focused in his paper only on the influence of ENSO on the coffee prices. Coffee is produced mainly in equatorial and sub-equatorial parts of the world, which are the epicentre of an ENSO event. Ubilava investigated two different sorts of coffees. There are two main species of coffee, namely the Arabica[4] and the Robusta. These two coffee varieties have totally different characteristics, and are produced at different geographical locations. Central America is the largest producer of the Arabica sort, whereas Robusta is predominantly produced in Southeast Asia. An ENSO event causes weather conditions for coffee to improve in Central America and worsen in Southeast Asia. The consequence is that El Niño therefore leads to lower (higher) prices of the Arabica (Robusta). So, we can conclude that the influences of El Niño differ per

[3] Earlier research used dummy variables to measure the effect of El Niño

[4] Also the IMF differentiates the Arabica from the Robustica, this paper only investigates the Arabica.

geographical area. Besides that, Ubilava (2012) also finds a strong nonlinear connection between ENSO and coffee prices. The effects of El Niño on the coffee prices remain significant for around a year.

Cashin et al. (2012) examined relationships between ENSO and economic variables like GDP per country, commodity prices and inflation. They used an extensive multi-country framework, that also took spillovers into account. Cashin et al., just like Ubilava (2012), found compelling evidence for heterogeneous effects of El Niño on different parts of the world. For example, Australia, experiences significant negative output growth. This is partly caused by lower crop yields (e.g. wheat) as a consequence of the changed weather conditions. So, the direct impact on (food)commodities works its way through, so that whole countries gets affected by an ENSO event. According to Cashin et al., the effect on non-oil real commodity prices is at its peak around three quarters after the first surprise in SOI, with a price increase of more than 5 percentage point. Besides that, they also find that an El Niño creates a demand shock in the developed western world, increasing the commodity prices even more. So, the evidence that El Niño has an impact on world-wide economic variables is striking. However, there is no consensus between the different studies on how strong the relationship is, and how long it affects the concerning variables.

2. Hypotheses development

To be able to answer the main research question of this paper, several hypotheses will be tested. In total, this paper contains two hypotheses, the main question excluded. Altogether, the outcome of the hypotheses will be sufficient to conclude the answer on the research question of this thesis.

2.1 Hypotheses

As this paper uses the most recent data up till data (the latest El Niño was in 2016), there is also the opportunity to research the effect if technological innovation, more developed agriculture and globalization, reduces the effect of an El Niño. Assuming that there is indeed an influence found by El Niño on the commodity prices, the first hypothesis is:

'*The influence of El Niño on commodity prices is getting smaller as we move up in time'*

It is very uncertain what the result of this hypothesis will show. Although one can argue that a more developed agriculture can protect the crops better against more extreme circumstances, the effects could still be ambiguous. A report from the Worldbank states that climate change and an increase in climate variability could especially be harmful to the tropical countries, as agriculture is an important source of life in those countries (Worldbank, 2003). These countries are the epicentre of El Niño events, an extreme example of increasing variability. Also the global warming could play a role in how ENSO develops over time. However, what the impact of this phenomenon on the ENSO cycle will be, is still very uncertain (Collins et al., 2010).

The latest hypothesis researched in this paper is if the effect of an ENSO event on the commodity prices is nonlinear. Climatological research has shown that how stronger the SOI-anomalies the stronger the El Niño event (Trenberth, 1997). And, as stated earlier, Ubilava (2012) found that for commodity prices this there is a nonlinear reaction to SST-anomalies. This will also be investigated in this paper. The second and final hypothesis is therefore:

'The effect of El Niño on commodity prices is, at least for a part, nonlinear'

Based on previous studies, the outcome of this hypothesis is very uncertain, as we cannot draw conclusions from one previous example. However, if another nonlinear effect is found, one has more reason to believe that this is actually the case. Especially because this paper investigates the effects for multiple commodities. Altogether, these hypotheses can answer the main research question of this paper.

2.2. Introduction to the food commodities

In section 2.1 is described what kind of consequences ENSO causes and was made clear that the normal weather conditions change dramatically when an El Niño event has occurred. This is especially the case for the centre of El Niño, where it strikes the hardest. Mostly, this are equatorial and sub-equatorial regions, which are also important producers of many food commodities (Ubilava, 2012). Therefore, I chose to narrow down the scope of this thesis and focus on the countries at the epicentre of El Niño and the most important commodities that they produce.

This paper examines for six food commodities in total what the influence of El Niño is on the prices of the concerning commodities. The investigated commodities are: Fish, Rice, Coffee, Cacao, Soybeans and Palm Oil. In the next section follows for each commodity an introduction, its characteristics and the most important producers. Thereafter, the expected effect of ENSO events on the prices are given, by taking into account the biggest producers and the paired weather consequences of an El Niño per commodity. The results are summarized in table 1.

2.2.1. Cocoa

Cocoa gets produced in 20 countries worldwide (UTZ, 2017). Cocoa demands tropical conditions in order to grow well. Therefore, Cocoa producing countries are only located in (sub-)equatorial areas. The biggest producer on continental level is Africa (63.8%), followed by Central-America and South-America combined (18.7%). Asia, the number third, is responsible for 16.1% of the production. However, Indonesia is responsible for more than half of the total production in Asia (FAO,2015). Although many countries produce cocoa, so that losses in one area can be compensated by more favourable conditions in other areas, it is still expected that the cocoa price rises. This is due to the fact that most producers face less favourable conditions during ENSO events than during normal conditions. More favourable conditions during El Niño is only experienced by small parts, like the southern part of Brazil.

2.2.2. Coffee

Coffee can be classified in two main species, the Arabica and Robusta (Ubilava, 2012). The Arabica is more vulnerable to exogenous conditions, like the weather (ICO, website). Therefore, I chose to investigate only the Arabica in this paper. Ubilava (2012) found in his research on the relationship between coffee prices and El Niño that the price of the Arabica decreases in the after move of an El Niño. This effect is mainly caused by the characteristics of the Arabica; little climates are suited to produce the

Arabica. The regions that do suit these characteristics (like Brazil), faces favourable weather conditions during El Niño. Therefore, it is expected that a negative relationship between El Niño and the price of Arabica is found.

2.2.3 Rice

Rice requires very specific conditions to grow well. Southeast Asia is the only region that fulfil these specific conditions. In total, 91% of the total rice produced worldwide is coming from this region, with the countries China, India and Indonesia as the biggest producers (FAO, 2014). Because rice is mainly produced in a relatively small area, and this area faces negative consequences during El Niño, it is expected that the rice price increases after an El Niño event.

2.2.4. Peruvian Fish

The IMF provides the prices for multiple kinds of fish. For example, the Norwegian Salmon and Peruvian Fishmeal. If one sort of fish faces consequences of anomalies in the sea temperature in the Pacific, it will be the Peruvian fishmeal. Therefore, this fish commodity is chosen to be investigated in this paper. The Pacific-Ocean near Peru is the absolute epicentre of El Niño. The temporary warmer ocean during ENSO events makes the living conditions for fish worse, which could lead to less successful fishery. All these factors taken into account, a positive relationship between El Niño and the price of Peruvian fishmeal is expected.

2.2.5. Palm oil

Palm oil is expected to react heavy to an ENSO episode. The exposure of this crop is enormous, 90% of the total palm oil productions occurs in Indonesia and Malaysia. The dry weather conditions during an El Niño in both Indonesia and Malaysia leads to much lower crop yields for the palm oil industry (Schroders 2015). So, a price increase is expected for the palm oil commodity in the after move of an El Niño.

2.2.6. Soybeans

Soybean yields are likely to improve during ENSO events, with 2.1% up to 5.4% on average (Lizuni, 2014). This is due to the fact that some major producers of soybeans face favourable weather conditions during El Niño. Besides that, the production of soybeans finds place worldwide, so that negative influences of ENSO events outweigh each other. Higher supply leads to a lower price, ceterus paribus. However, soybeans are a substitute for palm oil. Rising palm oil prices can therefore lead to higher demand to soybeans. The effect of El Niño on the soybean price is thus ambiguous and uncertain (Schroders, 2015).

Table 1. The expected effect of an El Niño event on the commodity prices

COMMODITY	BIGGEST PRODUCERS	EXPECTED RELATIONSHIP
Cocoa	(sub-) equatorial areas all over the world	?
Coffee (Arabica)	Brazil	Price decrease
Rice	Southeast Asia	?
(Peruvian) Fish	Peru	Price increase
Palm Oil	Malaysia and Indonesia	Price increase
Soybeans	Worldwide	?

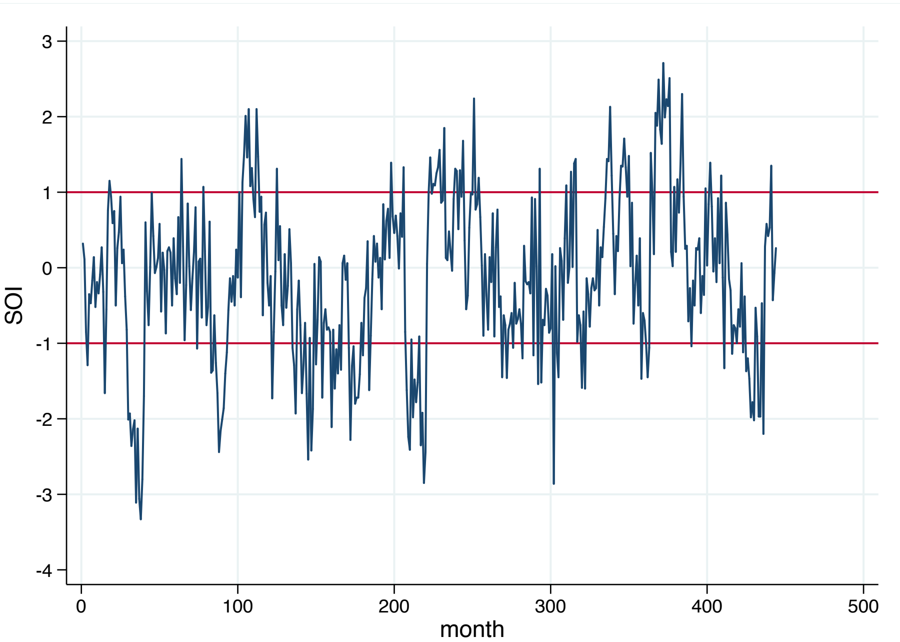
3. Data

3.1. ENSO Data

3.1.1 SOI data

The data about El Niño is collected from the Australian Government Bureau of Meteorology (BOM). This data entails the monthly 'Southern Oscillation Index' (SOI), from the year 1980 up till the end of 2016. There exist multiple methods to calculate the SOI and the used methods differ between climatological bureaus. The BOM uses the means and standard deviations of the 1933-1992 period to calculate the SOI. This differs from, for example, the American method, which uses a different time sample (1951-1980) as base period. Furthermore, the BOM multiplies the actual SOI-values with 10, and therefore uses a more precise number. Namely, the American National Oceanic and Atmospheric Administration rounds the SOI to one decimal, whereas the BOM uses two decimals. The methodology for calculating the SOI is explained in more detail in the methodology section. The SOI-values are divided by 10, so that there could be no misinterpreting of the coefficients. They do not need any further adjustments in order to be correctly used in the regressions. Table 2 and Figure 2 shows descriptive data about the ENSO variable SOI.

Figure 2. Time series line of the El Niño variable SOI.



The red lines indicate La Niña (1) and El Niño (-1) episodes

Table 2. Descriptive statistics of the SOI variable

Variable	Observations	Standard deviation	Minimum	Maximum	Mean
SOI	444	1.091932	-3.33	2.71	-0.1577252

In figure 2 is the time series of the SOI variable illustrated. There is a sort of pattern, with one in every year an El Niño episode. As stated in the literature section, most of the time an El Niño episode is followed by a La Niña episode. The strongest deviation of SOI is visible in the period around the 50th month, that is around 1984. However, the El Niño of 1987-1988 was one of the strongest in history (……), although the SOI does not show that. So, it is not that a lower (higher) SOI automatically indicates a heavier El Niño (La Niña). Besides the pattern in the fluctuations of the SOI, there is no other trend visible that would indicate that a negative or positive SOI appears more often moving through time.

3.1.2 Methodology of SOI

As discussed in section 1.2., this paper uses the Southern Oscillation Index as a proxy for El Niño, and, thus as the main variable in this thesis. This subsection includes a more extended motivation on why I chose the SOI as main variable and an explanation of how the SOI is constructed.

Brunner (2002), was the first researcher to investigate a continuous effect of El Niño on economic variables. In his research he used both the SOI and the SST and found that the SOI gives the strongest results when conducting academic research. Besides that, the NOAA (2016) states that taking the Sea Surface Temperature as an indication of El Niño, can lead to biased results. The reason for that is the sea temperature can differ locally. Not all researchers follow Brunner (2002) in his recommendation, e.g. Ubilava (2012) and Lizuni (2014), use the SST as proxy for El Niño. However, to be able to measure a continuous influence of El Niño on a certain variable, one should use or the SOI or the SST. In this paper, I follow the founding of Brunner (2002) and use the SOI as main variable and proxy of El Niño.

The SOI is a widely used method to measure ENSO activity (Kepenne, 1995). It is computed using the sea air level pressure (SLP) in the El Niño 3.4 region. The El Niño 3.4 region is the area between the two islands Tahiti (West-Pacific) and Darwin (East-Pacific). The calculation of the Southern Oscillation Index varies slightly per climatological bureau. The data of the BOM are used in this paper, and they use the following methodology:

$$SOI = 10\,\frac{(Pdiff - Pdiffav)}{SD(Pdiff)} \quad (3)$$

Where *Pdiff* is the one month mean sea air level pressure at Darwin minus the one month mean sea air level pressure for Tahiti (the El Niño 3.4 region). *Pdiffav* is the difference between the long term average sea level pressures of the 3.4 region. The denominator stands for the Standard Deviation of the long term average difference of the mean sea level pressures, to normalize the Southern Oscillation Index. I use a normalized value of the sea level air pressure in this paper, because this is common in both academic research and in the climatological profession. As described in the data section, the BOM multiplies the SOI by 10. However, they only do this as a convention. To avoid possible misunderstanding regarding the coefficients, this paper divides all the SOI values by 10 so that normal values are created.

3.2. Commodity prices

The database on the commodity prices include prices for six different commodities. This data is provided by the International Monetary Fund (IMF) and has a time span of 1980 until present. The prices are denominated in nominal U.S. Dollars, therefore, the commodity prices are deflated by the Consumer Price Index (CPI). The CPI is provided by the U.S. bureau of Labor Statistics, and concerns the monthly CPI of the United Stated, with base year 1983 valued 100. The commodity prices are quoted monthly, just as the SOI-values. To improve the quality of the regressions, the logarithmical returns of the commodities are calculated. First, the natural logarithms were taken from all the prices. Second, the differences between those logarithms where taken (formula 1 and 2). This entails that the first observation for each commodity is lost. From here forward, every time the commodity prices are stated it is to be considered as the logarithmic returns, unless stated otherwise.

$$logarithmic\ prices = LN(P_x) \qquad (1)$$
$$Return_x = LN(x_t) - LN(x_{t-1}) \qquad (2)$$

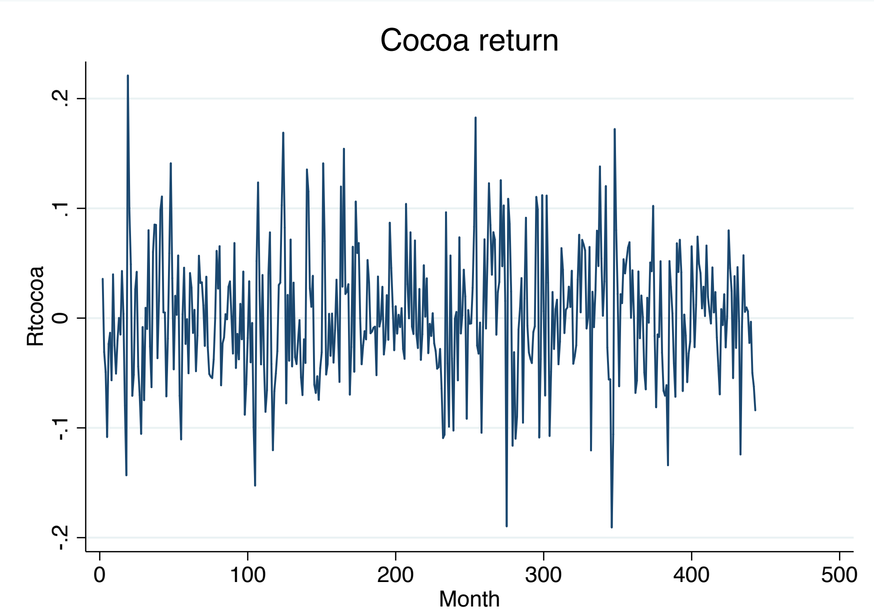
Table 3 shows the descriptive statistics of the logarithmic returns of the commodity prices. There is almost no difference between the returns of the different commodities. The only two things that are noticeable, are that all the six commodities have positive means, and that coffee and rice have somewhat higher maxima and minima. Figure 3 shows the graphed time series of the cocoa commodity[5].

[5] The differences between the commodities' statistics are negligible, therefore, only the cocoa commodity is shown.

Table 3. Descriptive statistics of the logarithmical returns

Variable	Observations	Mean	Std. Dev.	Maximum	Minimum
Cocoa	443	0.0020197	0.0591146	-0.1907096	0.2209954
Coffee	443	0.0027727	0.0772661	-0.358934	0.427235
Rice	443	0.0023573	0.0594914	-0.279917	0.420020
Fish	443	0.0031523	0.0491454	-0.2301863	0.261122
Palm oil	443	0.0030208	0.0781814	-0.3351717	0.290337
Soybeans	443	0.0035431	0.0574446	-0.2758381	0.255111

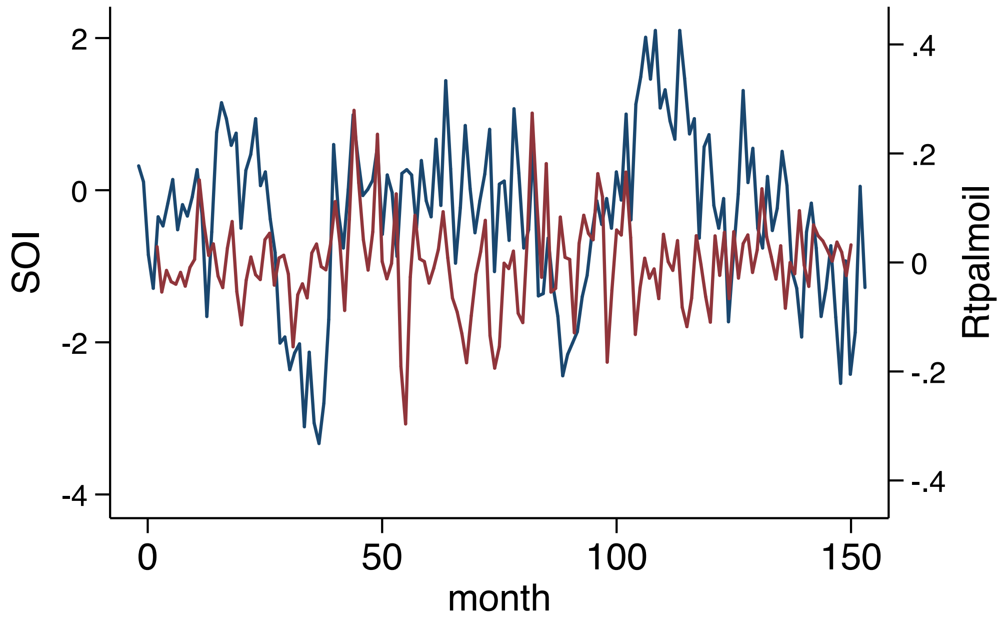
Figure 3. Time series graph of the logarithmic return of cocoa



The time series of the cocoa commodity has a mean of around 0. It contains a couple of extreme values. However, by looking at the figure, there is no indication that the data is non-stationary.

An anecdotal analysation is shown in figure 4, which displays the relationship between SOI and the price of palm oil for only the first 150 observations. Although it is just a visualisation of the relationship, one could notice that the price of palm oil tends to respond to the value of SOI. This will be further investigated in the methodology and the results section.

Figure 4. The relationship between the return of palm oil (red line) and the SOI variable (blue line) for the first 150 observations



4. Methodology

In this section, the methods of examining the effect of the ENSO-variable SOI on the commodity prices are discussed. All the methods described are tested on every single commodity described in section 3.2. So, every regression is run six times in total.

To test the common effect of the SOI variable on the commodity prices, a time series regression has been run. The logarithmic returns are regressed on lagged values of the SOI variable. For each lag an apart regression has been run. As described in the literature review section, there may be certain seasonal effects that influences both the commodity prices and El Niño. Therefore, seasonal control variables are also added to the regression. Those seasonal dummies are: Summer Fall and Winter, which are included in all the regressions run. The dummy Spring is not used to make sure there is no dummy trap. Here follows the regression run to measure the common effect of SOI on the commodity prices:

$$RtCocoa = SOI_{t-1}ß_1 + Summer\ ß_2 + Fall\ ß_3 + Winter\ ß_4 + \varepsilon \quad (4)$$

For each commodity 3 regressions of this form are run, so that the lagged effects of SOI for one quarter in total can be calculated. In the next regression of this series is thus the X-variable SOI_{t-2} included. Because just one lagged value of SOI is included, it is important to notice that the coefficients cannot be added to calculate the total effect. However, the returns can be calculated by taking the difference of consecutive months.

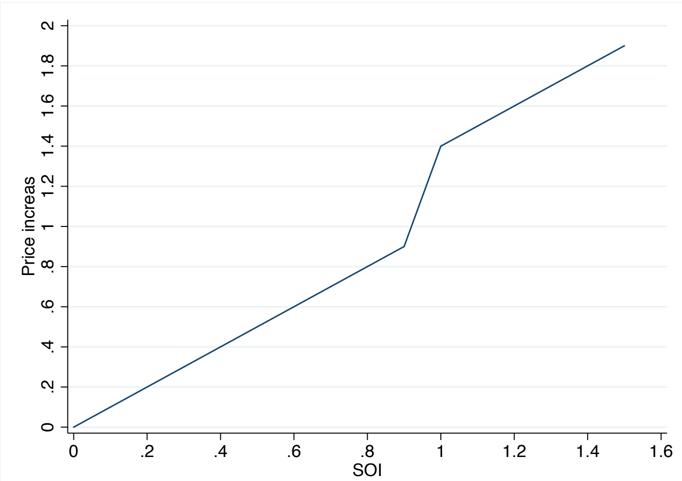
To test the first hypothesis, if there exists a nonlinear relationship between the SOI and the commodity prices, a dummy variable is added to the regressions. This dummy, called Nonlinear SOI, takes value one for every month that the SOI variable is smaller than -1. On this way, it can be examined if deviations further than -1 leads to nonlinear higher (lower) prices than just with the continuous SOI variable. How this would look like if there indeed exists a nonlinear effect, is made visible in figure 5.

The dummy variable NonlinearSOI is added to the regressions used for testing the common effect of the SOI variable. On this way, it is possible to test that extreme values of SOI influences the commodity prices more than smaller deviations of the long-term mean SOI. This entails that for testing the nonlinear relationship, the regression looks as follows:

$$RtCocoa = SOI_{t-1}ß_1 + NonlinearSOI_{t-1}ß_2 + Summer\ ß_3 + Fall\ ß_4 + Winter\ ß_5 + \varepsilon \quad (5)$$

Just like for the previous series of regressions, the nonlinear regression also is run 3 times for each commodity. So that for every month the effect of the SOI and the NonlinearSOI dummy on the commodity prices can be calculated.

Figure 5. Hypothetical nonlinear effect



In this example, the dummy Nonlinear SOI has a value of 0.4, which means that more than one unit deviations lead to a nonlinear higher price increase.

For the third hypothesis, to test whether the influence of the SOI on the food prices decreases over time, the dataset is divided into multiple samples. The full dataset contains 36 years (1980 to 2016), which are divided into three different samples. Each sample contains 12 years: 1980-1992, 1992-2004 and 2004-2016. Subsequently, the first series of regressions is tested again, but now for every time sample apart. Then the betas are graphed, so that it is visualized how the betas develop over time.

5. Results

This section shows the outcome of the tests and regression discussed in the methodology section.

The first regressions tested the common effect of the SOI-variable on the commodity prices. The dependent variable is the logarithmical return of the commodity prices and the independent variable is the SOI variable. Besides the SOI variable, the seasonal variables are also included in the regressions to control for omitted variable bias. The second series of regressions tries to answer the first hypothesis, if the SOI also has a nonlinear influence on the commodity prices. This is done using the dummy variable NonlinearSOI described in the methodology section. The final series of regressions tested the second hypothesis if the effect of the SOI variable gets smaller if we move up in time.

The results differ to some extend between the six different food commodities. However, all the commodity prices tend to react something to the SOI variable. Section 5.1 shows the results of the simple regressions, in section 5.2 the results of the nonlinear effect are assessed, and 5.3 investigates the time varying effect of the SOI variable. The results of the seasonal control variables are not of interest for this paper, therefore, the seasonal dummies are assessed in Appendix A. Appendix B provides a robustness checks with the Sea Surface Temperature as independent variable.

5.1. The influence of the SOI variable on the commodity prices

Tables 4a. and 4b. show the effect of the SOI variable on the returns for the first 3 months. It is important to note that each month shows the return relative to the lagged SOI value. The reason for this is that for each commodity three regressions has been run, each with one lagged value of SOI up to three months. The results are multiplied by -1. By doing this, the coefficients show the effect of a -1 standard deviation of SOI on the logarithmical returns. I chose to do this, so that the coefficients can be interpreted as the reaction of the prices to the circumstances comparable to an El Niño-like event.

For the Cocoa commodity, there is an upward price pressure in the first month and the third month. The coefficient for the second lag shows a negative price pressure. However, none of the coefficients are statistically significant, with P-values ranging between 0.45 and 0.88.

Just like the reaction of the Cocoa prices, the coffee prices also show little reaction to an anomaly of the SOI. Contrary to the Cocoa commodity, the coffee price decreases with around 0.06% in the first month, and with 0.12% the second month after an initial deviation of SOI. The coefficient for the third lag is slightly positive, meaning a little upward price pressure. Just like for the cocoa commodity, none the effects are statistically significant.

The time series regression of the SOI variable on the rice commodity do not show very convincing effects, with all P-values above 0.5. However, there is on average a price increase for all three months after SOI anomalies arise, varying from around 0.10% up to 0.17% in the third lag.

Peruvian Fish, shown in table 3b., shows a strong reaction to deviations in the air pressure. The decline in sea level temperature make the conditions for fish worse. This effect works its way through to the price of the Peruvian fish, which rises with 0.612% the first months after the deviation of SOI. This coefficient is significant at the 1% level. The price for Peruvian fish is even higher in the two months later, with a beta of 0.663. The upward price pressure decreases a bit in the third month, but even then there is still a higher price visible for the Peruvian fish, which is also significant.

The price of palm oil also shows a significant reaction to the SOI variable. The first lagged month has a coefficient of 0.604% with a p-value of 0.046. The second months has an even stronger reaction; a price rise of around 0.77% and significant at the 1% level. In the third month after the SOI anomaly, the upwards price pressure decreases, although the price is still significantly higher than under normal SOI circumstances.

Soybeans do have the least significant reaction to SOI anomalies. Although the coefficients for all three months indicates a small price increase on average, the values do not cross the 0.1% line and the p-values range between 0.69 and 0.862.

Table 4a. Results for the Cocoa, Coffee and Rice commodities

Lag	Cocoa	Coffee	Rice
1	**0.29874** (0.80232)	**-0.06266** (0.855)	**0.15875** (0.594)
2	**-0.03561** (0.45557)	**-0.12026** (0.712)	**0.10761** (0.723)
3	**0.03925** (0.884)	**0.0997** (0.782)	0.16851 (0.543)

Table 4b. Results for the Peruvian Fish, Palm oil and Soybeans commodities

Lag	Peruvian Fish	Palm oil	Soybeans
1	**0.61209** (0.003) ***	**0.604** (0.046) **	**0.06763** (0.778)
2	**0.66267** (0.001) ***	**0.76937** (0.008) ***	**0.0361** (0.862)
3	**0.37695** (0.07) *	**0.54907** (0.051) *	**0.09368** (0.69)

5.2. Nonlinear effects of SOI

In table 5a to 5e the estimated coefficients of the nonlinear regressions are shown. These regressions are the same as in the results described above, however a dummy is added to create a possible nonlinear effect. If the dummy is statistical significant, it would imply that more extreme deviations from the average air pressure (i.e. lower SOI values), leads to an even stronger influence on the commodity prices.

It is notable that the coefficient $ß_1$, the coefficient that shows the impact of SOI, changes dramatically when the dummy NonlinearSOI is included. This is the case for the cocoa, coffee and rice commodity. Also, the SOI coefficient lost its significance for the Peruvian fish and palm oil commodities. Besides that, the NonlinearSOI does not have any statistical significance, expect for the second lagged month of the soybeans commodity. For the soybeans, the NonlinearSOI dummy shows the most constant results, with 3 month of downward price pressure. However, those commodities did have the least significant results, also in the continuous regressions described in section 6.1. Besides that, it is also remarkable that the NonlinearSOI dummy takes negative values for all three lagged months for the soybeans commodity. The second lagged month is even statistically significant at the 10% level. This could mean that stronger deviations of SOI leads to more favourable weather conditions for soybeans to grow in. The only other significant influence of the NonlinearSOI dummy is found for the third month of the rice commodity. An upward price pressure of 1.7% is found, although the coefficient of the SOI variable has a downward price pressure in this case of around 0.31%. No other statistical significant results are found, and besides that, the results are ambiguous.

Table 5.a to 5e. Results for the nonlinear regression

Cocoa Lag	SOI	Nonlinear SOI
1	**-0.003** (0.99)	**1.0865** (0.26)
2	**-0.488** (0.20)	**1.65279** (0.09*)
3	**0.229** (0.58)	**-0.68092** (0.49)

Coffee Lag	SOI	Nonlinear SOI
1	**-0.654** (0.14)	**2.149** (0.11)
2	**-0.077** (0.87)	**-0.160** (0.91)
3	**0.612** (0.23)	**-1.84012** (0.14)

Fish Lag	SOI	Nonlinear SOI
1	**0.460** (0.147)	**0.554** (0.462)
2	0.61644 (0.047**)	0.16897 (0.824)
3	0.19515 (0.544)	0.65312 (0.434)

Palmoil Lag	SOI	Nonlinear SOI
1	**0.717** (0.137)	**-0.410** (0.736)
2	**0.698** (0.149)	**0.200** (0.829)
3	**0.131** (0.758)	**1.503** (0.165)

Soybeans Lag	SOI	Nonlinear SOI
1	**0.224** (0.557)	**-0.569** (0.561)
2	**0.457** (0.159)	**-1.537** (0.083*)
3	**0.013** (0.681)	**-0.155** (0.855)

Rice Lag	SOI	Nonlinear SOI
1	**0.133** (0.765)	**0.092** (0.927)
2	**-0.011** (0.981)	**0.434** (0.685)
3	**-0.317** (0.416)	**1.743** (0.078)*

5.3. The time varying effect of SOI on the commodity prices

To test the second hypothesis, if the influence of El Niño gets smaller as we move up in time, three different time samples were created. Subsequently, for each commodity the same regressions are run as in section 6.1. The results are shown in diagram 1a to 1e[6]. The outcome differs significantly from the regressions run on the total time period, and also differ between the time samples.

For the cocoa commodity, still none of the found results are statistically significant. However, the impact of El Niño on cocoa is subject to change. Namely, for all the lagged months, the 2004-2016 time period have the smallest coefficients. In this period, it is even the case that the coefficient for the third lagged month is negative, indicating a price decrease of -0.5% on average relative to a SOI of -1.

In diagram 3b. the effect of ENSO on the coffee is visualised. The trend of the coefficients is less clear for coffee than cocoa, especially for the first two lags. However, the coefficient of the third lag moves closer to 0 moving from the first time sample to the third time sample.

For the rice commodity, the diminishing influence of SOI is strongly visible. The other thing that is notable, is the rising influence of SOI during the 1992-2004 period. This phenomenon does raise the question if the diminishing effect of SOI is only due to developments like globalization and better protection of agriculture to weather circumstances. Many other factors could also have an influence. Especially, because the effects also get smaller for the price of Peruvian fish, which shows a constant decline of the coefficients for every time sample. Where crops growing on land can be better protected by the farmers and scientists who produce them, fishermen cannot protect the fish from rising sea temperatures.

The time varying effect on the palm oil returns is the strongest of all investigated commodities, with declining coefficients for all lagged months in the 2004-2016 time sample. A one standard deviation of SOI even leads to negative price pressure for palm oil two and three months after the deviation. Soybeans also faces a similar effect. However, the rising coefficient for the first lagged month in the 2004-2016 time sample is notable, which leads to the question if the effect is different for every commodity.

Although most of the food commodities tend to experience less impact of the SOI-variable on the returns in the most recent periods, many other factors will play a role in this. However, it could be the case that financial markets learnt to deal with the impact of the El Niño variable SOI. As written in the introduction, some of the headlines in the financial newspapers spoke of rising prices in wait of El Niño. The cause of this phenomenon does not get answered in this thesis.

[6] When no bar is visible for a certain time sample, the coefficient is too close to 0.

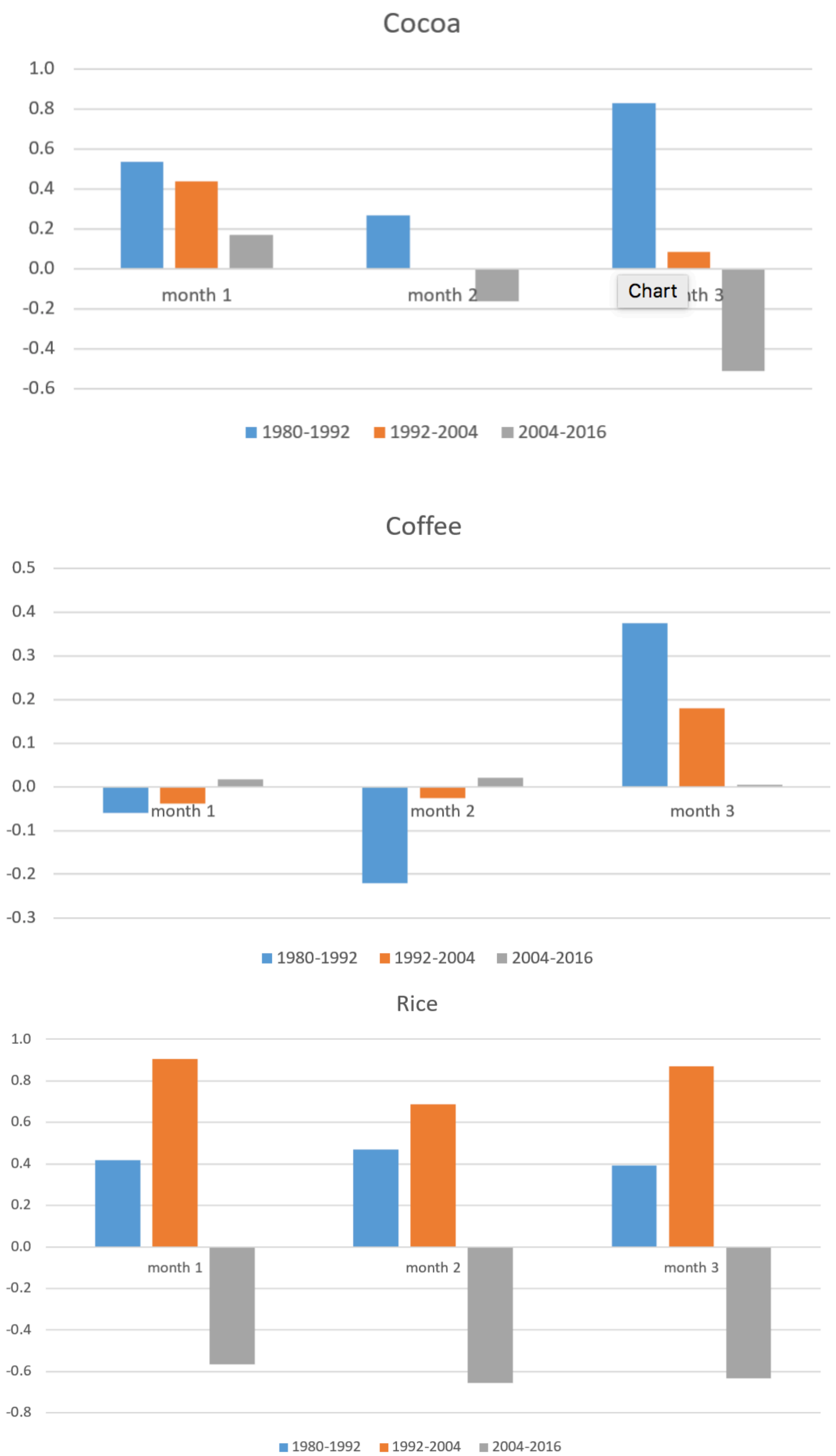


Diagram 3a. to 3c. Bar charts showing the different reaction of the commodities prices through time.

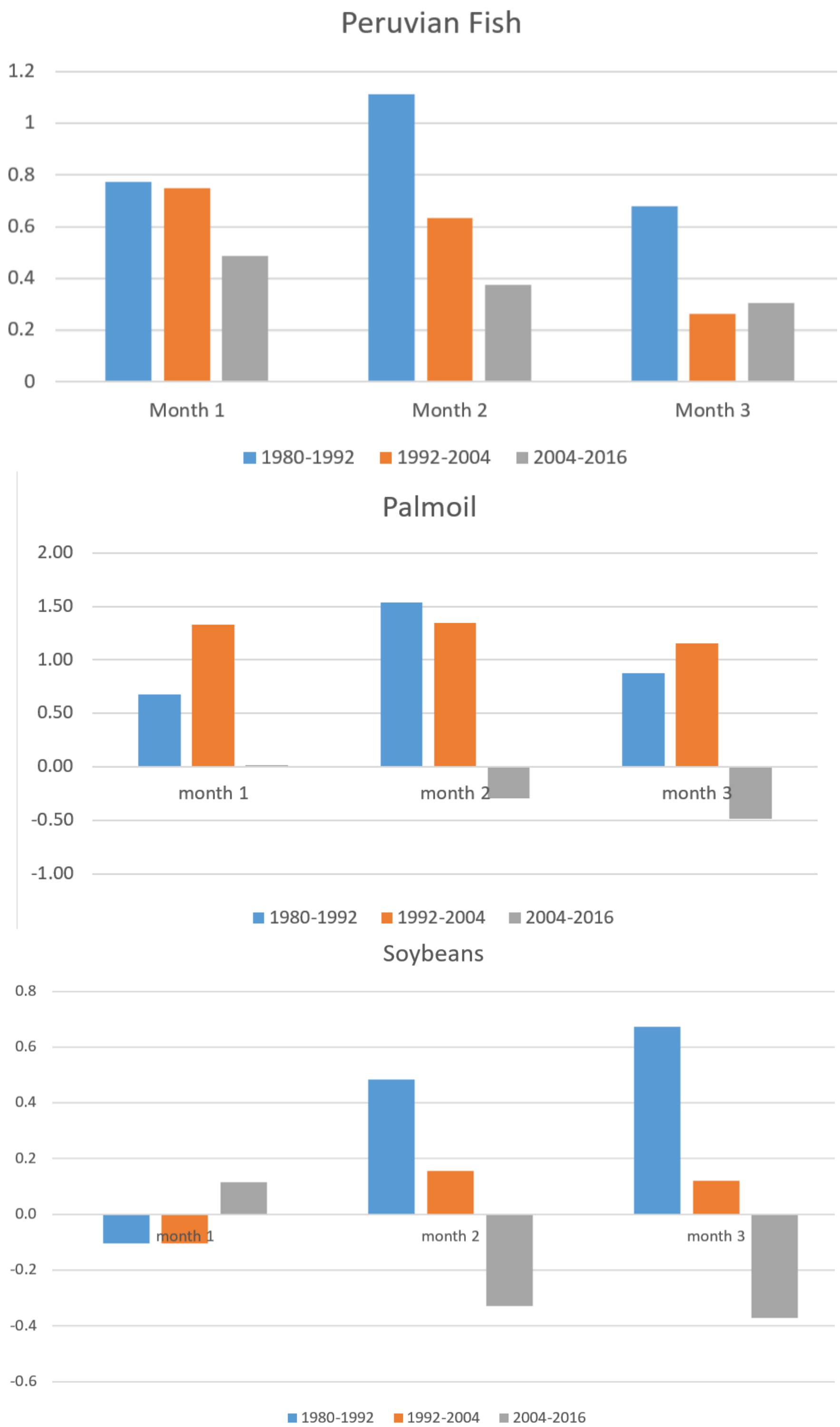


Diagram 3d. to 3f. Bar charts showing the different reaction of the commodities prices through time.

6. Conclusion

This thesis focussed on the influence of the El Niño proxy, the Southern Oscillation Index, on selected food commodities. The selected food commodities were: Cocoa, Coffee Robusta, Rice, Peruvian Fish, Palm oil and Soybeans. Those commodities were chosen because the main producers of them are facing directly the weather consequences of El Niño episodes. The SOI was used as main variable in this thesis for two reasons; the first one is that the SOI gives the opportunity to measure continuous influence of the ENSO cycle. Besides that, earlier research has shown that the SOI variable is preferred above the Sea Surface Temperature when conducting academic research to economic impact of El Niño (Brunner, 2002).

The central research topic of this thesis was: 'The impact of the ENSO proxy – the Southern Oscillation Index- on the food commodity prices. This paper has shown that for some food commodities there is indeed a (strong) reaction visible in the prices in reaction to anomalies in the air pressure. However, significant results were only found for two out of the six commodities, namely the Peruvian fish and palm oil. Beforehand, those two commodities where also expected to show the strongest results. Peruvian fishmeal is produced for 100% in the epicentre of El Niño events - the Pacific Ocean- whereas palm oil is for 90% produced in a focussed area – Malaysia and Indonesia - which also faces severe consequences of El Niño. The other food prices, Cocoa, Coffee Robusta, Rice and Soybeans, were all less affected by the SOI variable. This thesis did not try to find out what the reasons for this these differences are. However, a possibility is that the weather consequences of SOI anomalies leads to more favourable weather conditions for one area, whereas other faces less favourable condition and that those effects compensate each other. Another reason could be that the SOI proxy does not meet the requirements to measure this impact correctly. Namely, one speaks of a real El Niño episode when the SOI anomalies finds place for longer periods of time (BOM, Website). Therefore, SOI-deviations for only a short period of time may not have enough impact on the growing conditions, so that prices are not affected.

The research consisted out of the main research question together with two hypotheses. The main question was if the SOI variable has an influence on the commodity prices. For the cocoa, coffee and soybeans commodity, I cannot conclude that the SOI variable affects the prices. The respective P-values were too high and the coefficients were inconsistent. For rice, the effect was somewhat more visible; all the coefficients were positive, meaning an upwards price pressure up to three months after a negative deviation of SOI. However, the results were not statistically convincing, with the P-values ranging around the 0.6 for all three lagged months. The only significant results are found for palm oil and the Peruvian fish prices. The upward price pressure is strongest in the second lagged month, with a price increase of 0,77% for palm oil and 0.66% for the Peruvian fish relative to a SOI of -1. For both commodities, also the first and the third lag are statistically significant.

The first hypothesis investigated whether there exists a nonlinear relationship between SOI and the food prices. This was tested by adding a dummy variable –El Niño- to the regression. The El Niño dummy took value on when the deviation of SOI was larger than -1. The results were ambiguous and there seemed to be no nonlinear relationship between SOI and the prices for any of the commodities.

For the second hypothesis, the data was divided into three time samples, so that I could test if the influence of SOI changed over time. The results found that the influence of SOI weakens over time, with the prices in the 2004-2016 period facing less consequences of SOI deviations. However, the results seemed too extreme, suggesting that other factors play a role in this phenomenon. Unfortunately, I could not find out what the causes of this strongly diminishing effects of SOI are.

Concluding, this research has shown that some commodity prices do react to the SOI variable, and that the reaction varies per commodity. The most important factor in this relationship is presumably where the biggest producers of the concerning commodities are located. Production focussed in small areas tend to react heavier than production located over whole (sub-)equatorial areas. Besides that, it looks like the financial markets and/or the agricultural players anticipate on possible consequences of El Niño like events, by taking into consideration the diminishing lagged effects of the SOI variable on the prices. However, this remains uncertain, as the underlying reason is not researched in this thesis.

One suggestion for further research is to see where these diminishing effects are coming from. Before that, it is recommended to investigate whether these effects are real, or if it is just coincidence, which is also a possibility. Other suggestions for further research is to dive deeper into the food commodities that do react to anomalies in SOI. Thereby helping farmers to anticipate on the possible consequences and to reduce the number of failed crops. Besides that, when deeper research is done into the relationship between SOI and affected commodities, a possible winning strategy for investors could be created.

However, this research also has a couple of shortcomings. At first, the statistical methods used for this paper are not sufficient to conclude something with full certainty. Also, no tests have been run to check the characteristics of the data, like (non-)stationarity.

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Appendix

Appendix A

The seasonal control variables often showed significant results. It varied per commodity which season coefficient was significant. For most of the commodities – Rice, Palm oil, and Cocoa- summer lead to higher prices, whereas winter months often showed negative coefficients. Soybeans experience the biggest price increase during fall, on average. The influence of the seasons on the price is ranging between (-)0.8% up to almost (-)2%. Because many regressions are run during this paper, and all of them had the seasonal control variables included, it are too many coefficients to show in a table. Therefore, I chose to only describe the reaction of the control variables.

Appendix B. Robustness checks

Table 1a. and 1.b. Regressions with the Sea Surface Temperature as independent variable.

	Cocoa	**Coffee**	**Rice**
SST Lag 1	*0.137*	*-0.346*	*-0.287*
SST Lag 2	*0.035*	*-0.26584*	*-0.142*
SST Lag 3	*-0.038*	*-0.207*	*0.078*

	Peruvian Fish	**Palm oil**	**Soybeans**
SST Lag 1	*0.422*	*0.418*	*-0.508**
SST Lag 2	*0.270*	*0.491*	*-0.440*
SST Lag 3	*0.231*	*0.650**	*-0.438*

*is significant at 10% level, ** is significant at 5% level and *** is significant at 1% level.

The results are less significant as the regressions with SOI as independent variable. However, this was also expected, as Brunner (2002) already described that phenomenon in his paper. The effects are more or less the same as in the regressions with SOI, besides that they are somewhat less significant. The only noticeable difference is visible for the soybean commodity, which shows a constant negative price pressure, with the first month significant at the 10% level and the other two lags with p-values of around 0.11. So, the results are robust enough to hold on to the conclusions drawn in the conclusion section. I chose to only do a robustness checks for the regressions measuring the common effect of El Niño. The differences between SOI and SST were not significant and thus I considered the results as robust. Therefore, I did not find it relevant to examine whether this is the same for the regressions run for the hypotheses.