ARE THE COMMODITY MARKET PRICES AFFECTED BY EL NINO AND LA NINA?

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INTRODUCTION

As investors, we are interested on the factors that can affect the market price of commodities. In fact, identifying these factors and understanding the way they affect these price will help us to position ourselves on the market, in order to increase our profit while bearing the lowest risk.

Factors that continue to attract the attention of investors and traders are those related to climatic shocks, and in particular the global weather pattern known as El Nino. El Nino is defined as a climatic phenomenon related to the warm phase of El Nino Southern Oscillation (ENSO), an index used to assess and predict the global weather pattern. El Nino is characterize by warm temperatures anomalies in the South Pacific. It can trigger downpours or droughts and affect temperatures, threating crop yields and prices. Its twin sister La Nina, the opposite weather phenomenon, is characterized by cold temperatures. These two extreme weather conditions are most noticeable in South America, East Asia, South Asia, and Australia, with a modest impact in the Northern Hemisphere[1]. They can affect different economic sector, and most notably the agricultural sector and the mining industry.

Some studies have shown that commodities market prices are correlated to shocks on ENSO. For example, a study conducted by Allan D. Brunner[2] found that "ENSO account for almost 20% of commodity price inflation movement over the past several years".

Our study is line with previous studies on this topic, with the aim of updating our understanding of the relationship between ENSO and the market prices of some commodities. This study will focus mainly on three family of commodity prices: energy (non-fuel and fuel), minerals (metals), and agriculture (rice and wheat). By using monthly time series data from 1992 to 2015, we will try to assess the impact of El Nino or La Nina on the market prices of thesecommodities.

This report is organized as follow: in section 1 we will assess the main characteristics and properties of ENSO index, and those of the market prices of the commodities selected. In section 2, we will analyze the impact of ENSO on the price of these commodities by the mean of non-parametric regression approach and co-spectral analysis. Finally, the section 3 conclude.

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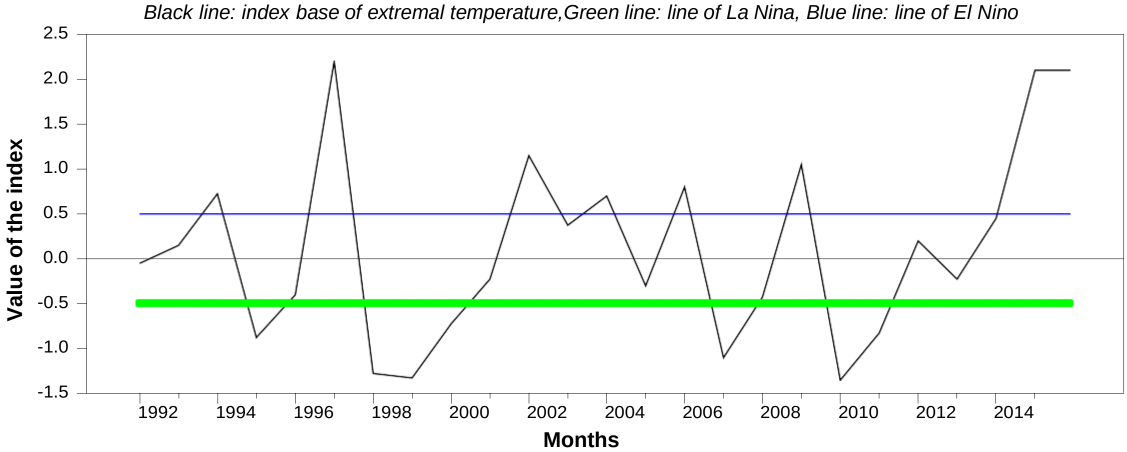
[1] World Bank Quaterly Report, " Commodity Markets Outlook : Understanding El Nino", October 2015
[2] Allan D Brunner, 2002, "El Niño and World Primary Commodity Prices: Warm Water or Hot Air?" Review of Economics and Statistics.

I-1 What do we need to know about El Nino and La Nina?

El Nino and its twin sister La Nina are both captured by the ENSO index, which represent a centered three-month mean of the Sea Surface Temperature (SST) anomaly. According to the National Oceanic Atmospheric Administration (NOAA), an event is categorized in the class of El Nino event if the ENSO index is at or above +0.5. This threshold is further breakdown into weak (0.5 to 0.9), moderate (1.0 to 1.4), strong (1.5 to 1.9) and very strong (>=2.0). If the ENSO index is at or below -0.5, the event is called La Nina. However, for an event to be categorized in any of the above categories, it must have equaled or exceeded the threshold for at least three consecutive 3-months period[3].

Figure 1 : Movements of ENSO index from 1992 to 2015

Black line: index base of extremal temperature,Green line: line of La Nina, Blue line: line of El Nino



As we can see from the above figure, 7 El Nino and 4 La Nina episodes were recorded during the period of the study (1992-2015). For El Nino episodes, the intensity vary from weak to very strong, while for La Nina, its vary from weak to moderate. The strongest episodes of El Nino were recorded in 1997-1998 and in 2015. For La Nina, the episodes with a high intensity were recorded in 1998-1999, just one year after the strongest episode of El Nino, and in 2010-2011. It can also be noted that this extreme and opposite weather conditions alternate most of the time during the period 1992-2015, and after an episode of El Nino the next episode occurs in 2 to 4 years. This gives us an idea of the periodicity of the El Nino phenomenon.

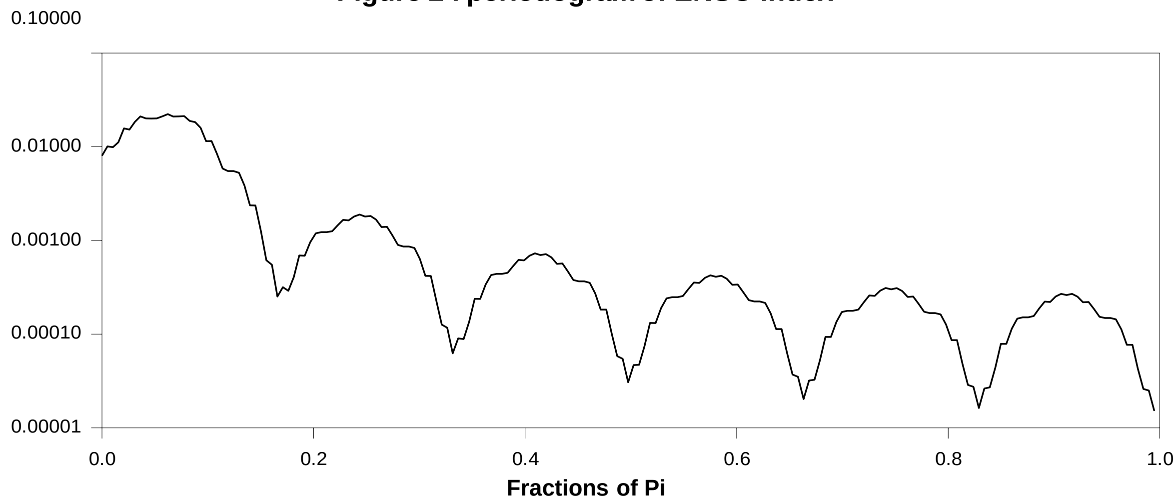
To better understand the periodicity of El Nino events, we conduct a spectral analysis on the ENSO index series, which account for both El Nino and La Nina events. The El Nino event

[3] World Bank Quaterly Report, " Commodity Markets Outlook : Understanding El Nino", October 2015

series is created from the ENSO index by considering only its value at or above 0.5. La Nina event series is also created from the ENSO index by considering only its value at or below -0.5. But before performing a spectral analysis, it is important to assess the stationarity properties of these series. This analysis is performed by using the Augmented-Dickey Fuller (ADF) test, which revealed that these series are integrated at order 1. Our series are not stationary in level and become stationary after the first difference. The spectral analysis is performed on the differentiated series.

The results of the spectral analysis are presented in the following figures. Figure 2 display the periodogram of the ENSO index, and the significant pics are observed at 0.066, 0.113 and 0.241 frequencies. These frequencies correspond respectively to 7.93 years, 4.6 years and 2.2 years' time period. The ENSO index has a long-term cycle which duration lies between 2 years and 8 years.

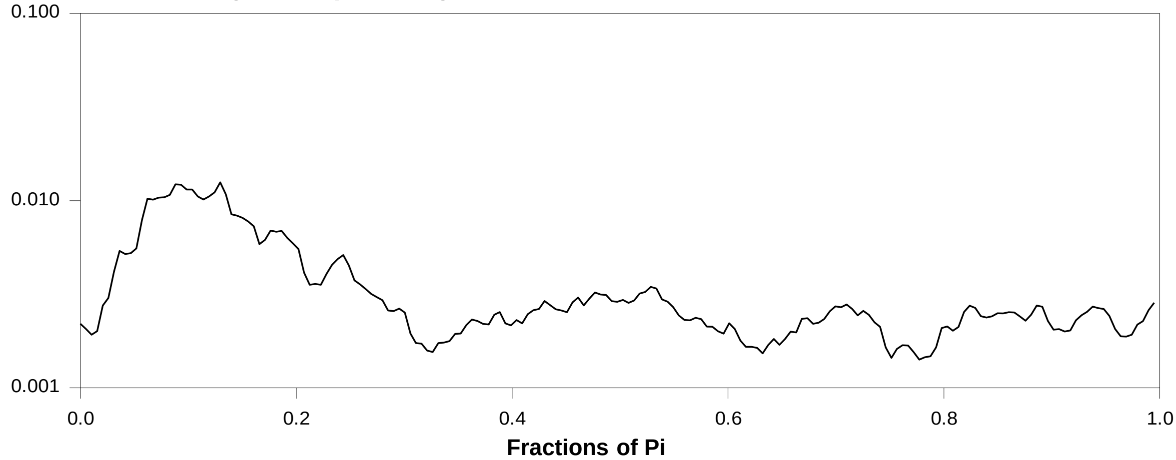
Figure 2 : periodogram of ENSO index



However, this spectral analysis don't give us any idea about the characteristics of the cycle of El Nino or La Nina event. In fact, as said before, ENSO index account for both opposite phenomenon.

When we carry out a spectral analysis only on the El Nino events (see figure 3) we can see that the main frequencies (frequencies at which we observe a pic in the value of the peridogram) are observed at 0.114, 0.194 and 0.276, which correspond respectively to a time period of: 4.6 years, 2.68 years and 1.89 years.

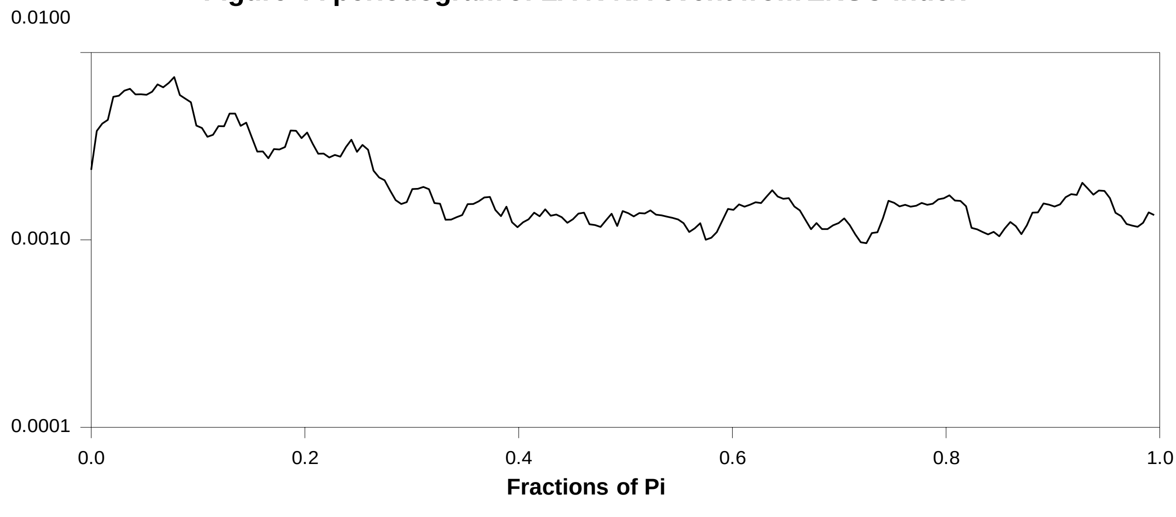
Figure 3 : periodogram of EL NINO event from ENSO index



When we perform the same analysis now only on La Nina events (see figure 4) we observe almost the same results. The main frequencies are 0.114 and 0.242 which correspond respectively to a time period of 4.6 years and 2.16 years.

We can say that both El Nino and La Nina events have a long-term cycle with a duration of 2 to 5 years. These opposite weather phenomenon occur with a periodicity of 2-5 years.

Figure 4 : periodogram of LA NINA event from ENSO index



I-2 The market prices characteristics of the commodities concerned by the study

In the present study we are interested in the market prices of: non-fuel energy, fuel energy, rice, wheat, raw agricultural material, and metal. Particularly, we are interested on the return prices of these commodities, which are computed by taking the first-difference of the logarithm of the prices. This choice ensure us to work with stationary series. The descriptive statistics of these series are presented in the table below.

Table 1: Descriptive statistics of the return prices of the commodities

Return prices	**Mean**	**Minimum**	**Maximum**	**Variance**	**Skewness**	**Kurtosis (excess)**	**Jacque-Bera**
Non Fuel	0.132	-16.897	8.247	6.997	-0.865***	5.945***	458.467***
Fuel	0.251	-26.935	16.495	46.435	-0.821***	1.514***	59.727***
Rice	0.087	-28.127	41.163	39.903	1.392***	10.455***	1399.890***
Wheat	-0.013	-25.292	24.713	45.816	0.176	1.508***	28.681***
Raw material	0.080	-17.660	8.012	9.002	-0.835***	4.108***	235.263***
Metals	0.204	-22.163	14.152	20.462	-0.248*	1.888***	45.598***

NB: *: significant at 10%; **: significant at 5%; ***: significant at 1%

From the table 1, we can see that during the period of study, the commodity with the highest return on average is fuel (0.251%), followed by metals (0.204%) and non-fuel (0.132%). Agricultural commodities (raw material, rice and wheat) exhibit the lowest return, on average, during the period of the study. However, it is for these category of commodities we observe a highest return (maximum values of returns) and the lowest (minimum values of returns) except for raw material. During this period, investors lost money on wheat, on average (-0.013% of return), which exhibit also a high variance. Therefore it was not a good idea to invest on wheat during this period. However, most of the commodities which exhibit a highest mean also have a high variance except for non-fuel commodities.

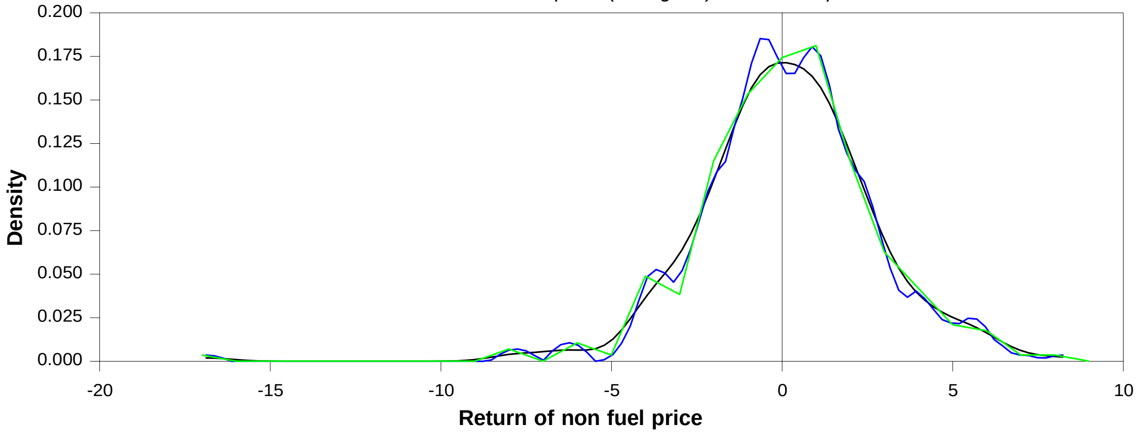
One can see also that these series don't follow a normal distribution given the high value of their Jacque-Bera statistics. They are also leptokurtic (have a fat tail) and most of them are skewed on the left except for rice (skewed on the right) and wheat (which is symmetric).

- **The return of Non-fuel price**

Figure 5 confirms the fact that the empirical distribution of the return of non-fuel price don't follow a normal distribution, bust instead follow an Epachenikov distribution. In fact, as one can see in this figure, the Epachenikov distribution fit well the empiric distribution. We can also see that the return of non-fuel price has a fat tail and is skewed on the left, which confirmthe results of table 1.

Figure 5: Distribution of the return of non fuel price

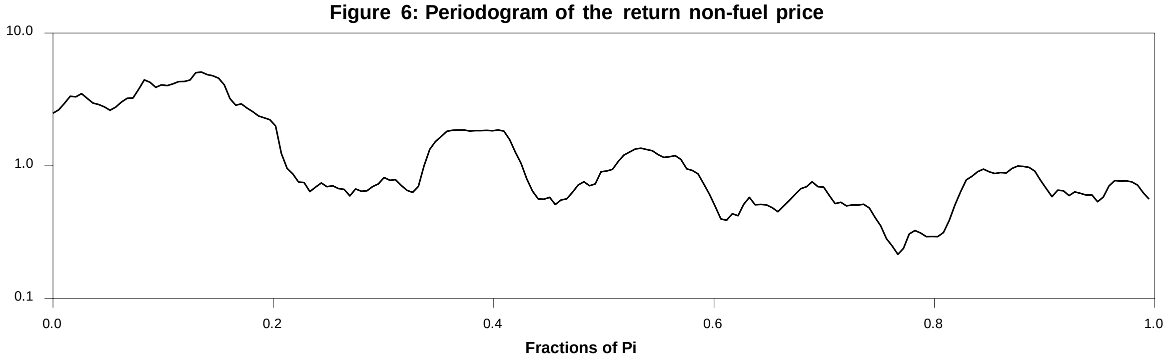
Black line:Gaussian, Green line:Empirics (Histogram), Blue line: Epachnikov



The analysis of the autocorrelation function (see figure 7) of the return of non-fuel price reveals that it has a short memory. In fact, above 6 or 12 months lags the past value of the return of non-fuel price don’t affect its current value.

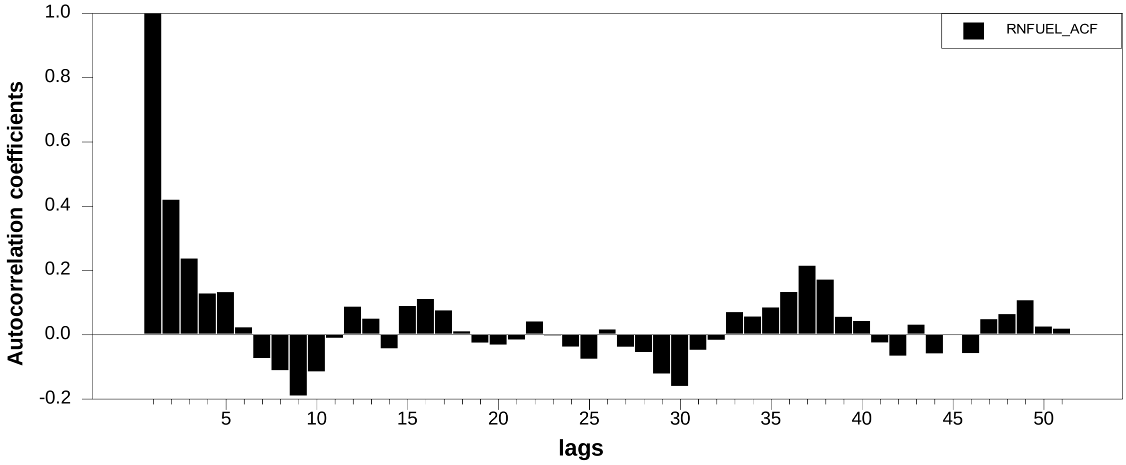
In connection with this result, the spectral analysis of this price return (see figure 6) shows that the main frequencies are at 0.41, 0.75 and 0.94 which correspond respectively to a time period of 1.28 year, 8 months and 6 months.

Figure 6: Periodogram of the return non-fuel price



We can then conclude that the return price of non-fuel has a short-term cycle with a duration between 6 months and 1 year.

Figure 7: ACF OF THE PRICE RETURN OF NON FUEL

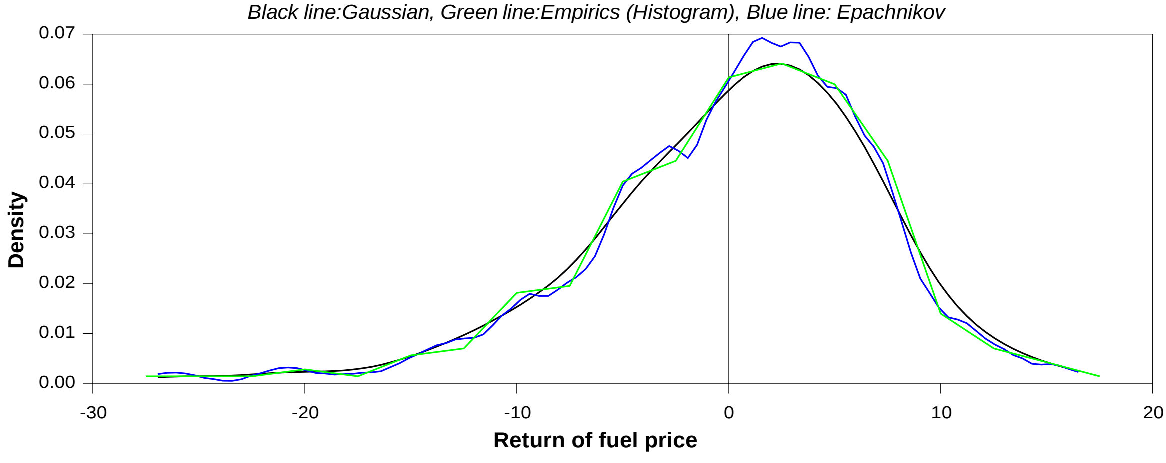


- **The return of Fuel price**

From the figure 8, one can see that the empirical distribution of the return of fuel price don't follow a normal distribution, bust instead follow an Epachenikov distribution. In fact, the Epachenikov distribution fit quit well the empiric distribution. We can also see that the return of fuel price has a fat tail and is skewed on the left, which confirm the results of table 1.

Figure 8: Distribution of the return of fuel price

Black line:Gaussian, Green line:Empirics (Histogram), Blue line: Epachnikov



We can see also from the analysis of its autocorrelation function (see figure 10) that the return of fuel price has a short memory, which is shorter than the memory of the return of non-fuel price. In fact, above 5 months lags, the past value of the return of fuel price don't affect its current value.

In connection with this result, the spectral analysis of this price return (see figure 9) shows that the main frequencies are at 1.15, 1.29 and 1.75 which correspond respectively to a time period of 5.44 months, 4.83 months and 3.57months.

Figure 9: Periodogram of the return of fuel price

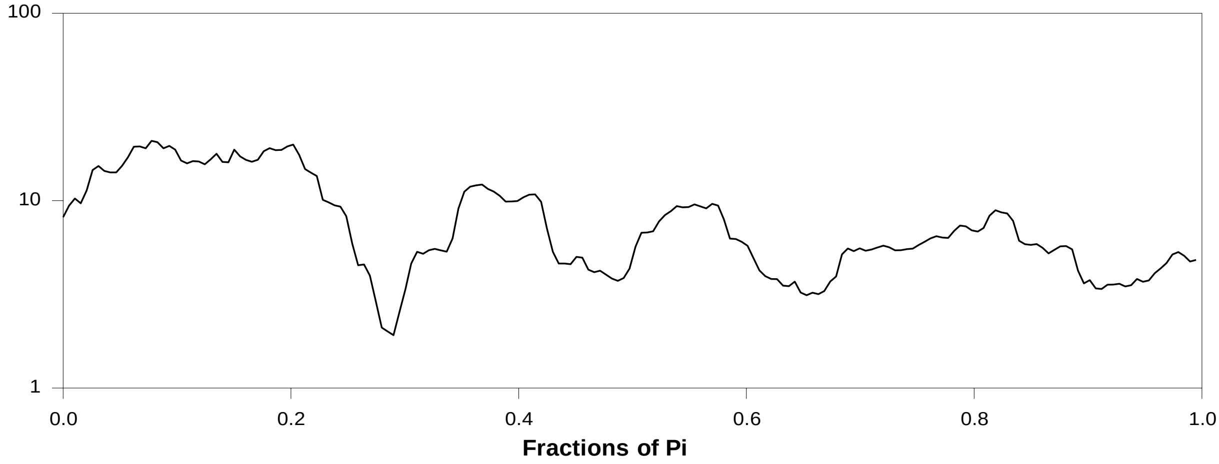
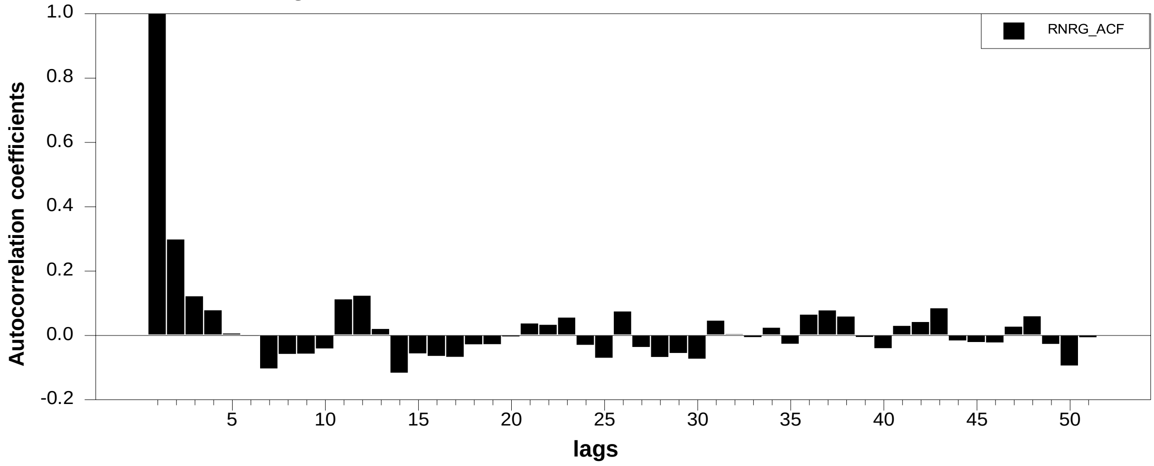


Figure 10: ACF OF THE PRICE RETURN OF FUEL



We can then conclude that the return of fuel price has a short term cycle with a time duration of 3 to 5 months. Therefore, the best predictor of the current value of the return of fuel price is its past 3 to 5 month's values.

- **The return of Rice price**

From the figure 11, one can see that the empirical distribution of the return of rice price don't follow a normal distribution, bust instead follow an Epachenikov distribution. In fact, the

Epachenikov distribution fit quit well the empiric distribution, even if the Gaussian distribution do well too. We can also see that the return of rice price has a fat tail and is skewed on the right, which confirm the results found in table 1.

The analysis of the autocorrelation function (see figure 13) of the return of rice price shows that, this series has a very short memory in comparison to the previous series. In fact, the current value of the return of rice price is affected only by its past 2-3 month's values.

In connection with this result, the spectral analysis of this price return (see figure 12) shows that the main frequencies are at 1.15, 1.50 and 2.16 which correspond respectively to a time period of 5.44 months, 4.16 months and 2.89months.

The return of rice price has a short term cycle with a duration of 2 to 5 months. Therefore, if a shock on this return is observed today, it will last for 2 to 5 months before we can observe another shock.

Figure 11: Distribution of the return of rice price

Black line:Gaussian, Green line: Empirics (Histogram), Blue line: Epachnikov

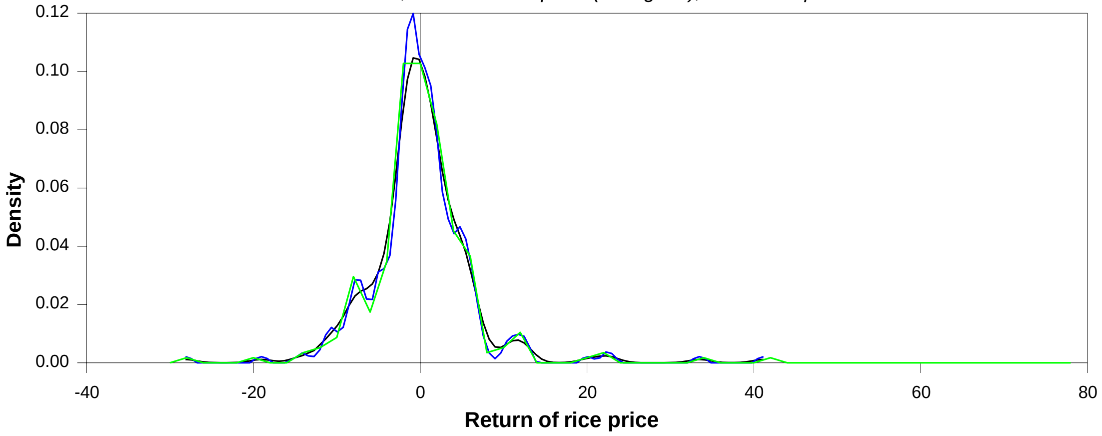


Figure 12: Periodogram of the return of rice price

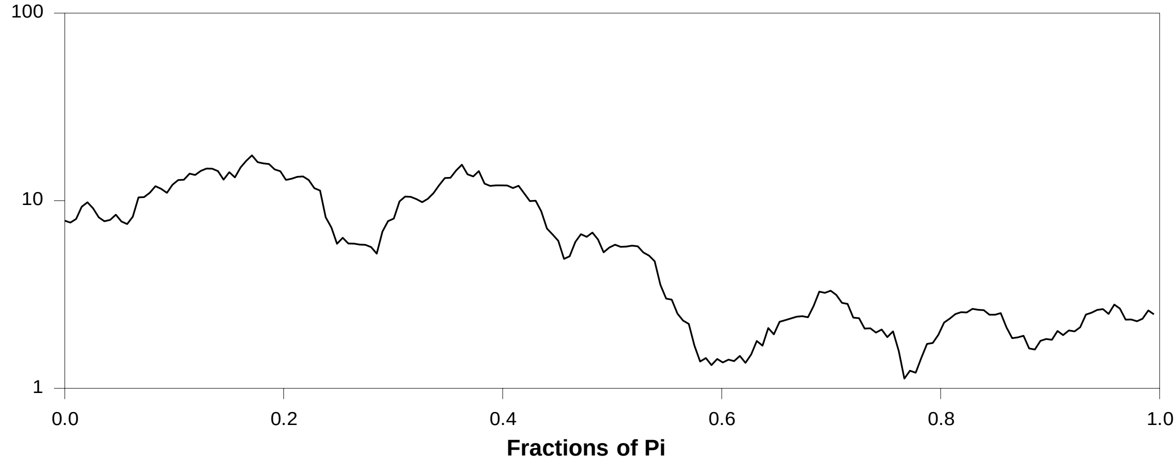
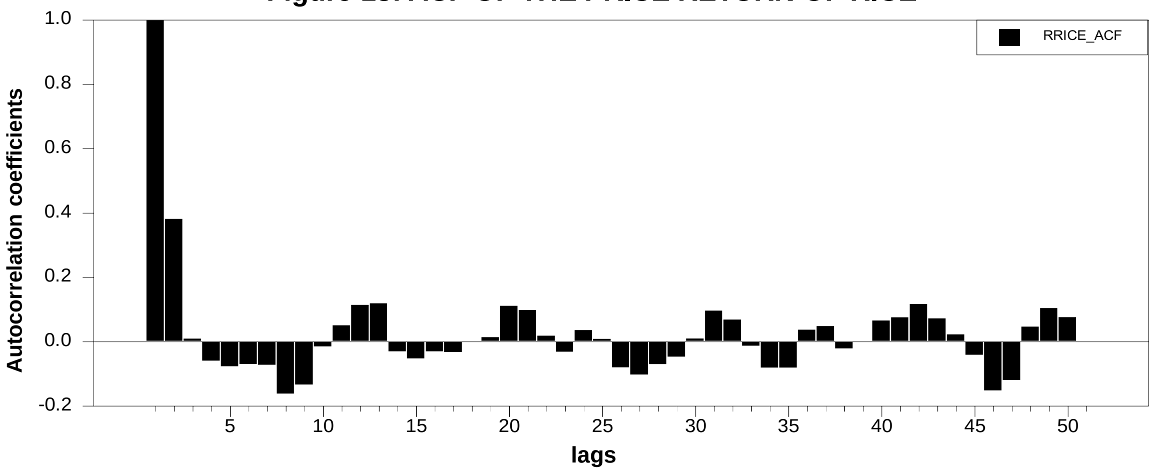


Figure 13: ACF OF THE PRICE RETURN OF RICE



- **The return of Wheat price**

The figure 14 shows that the empirical distribution of the return of wheat price don’t follow a normal distribution, bust instead follow an Epachenikov distribution. In fact, the Epachenikov distribution fit quit well the empiric distribution. We can also see that, even if, the return of wheat price has tails, it is not skewed, which means that its distribution is symetric.

Figure 14: Distribution of the return of wheat price

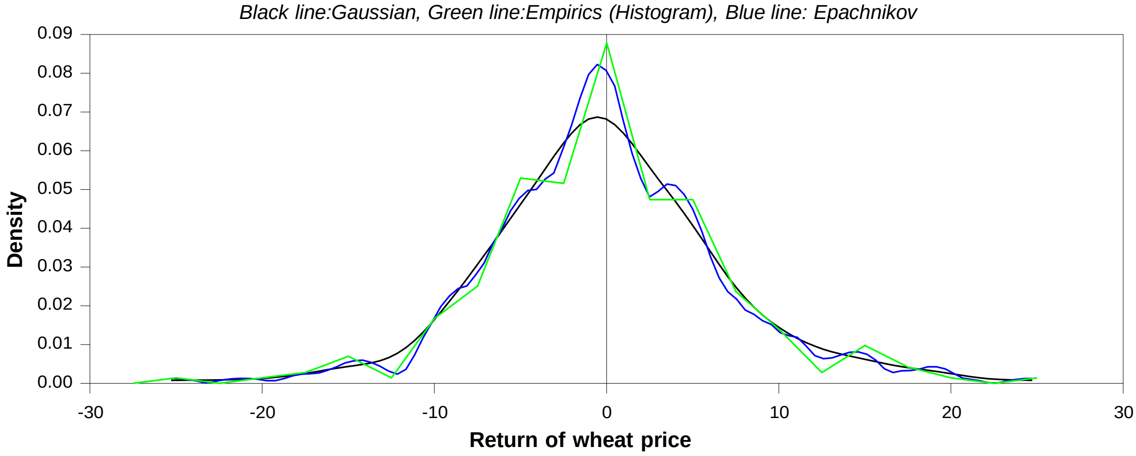
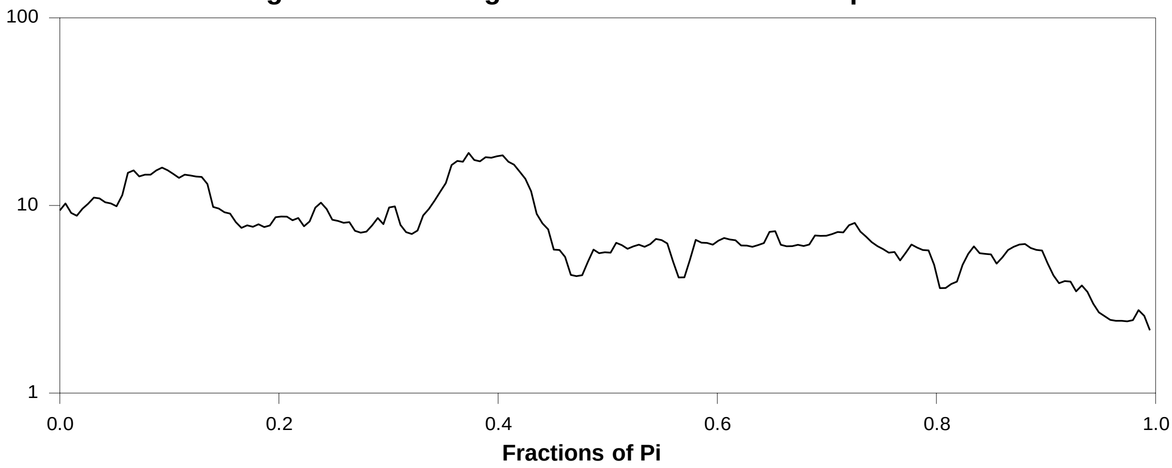


Figure 15: Periodogram of the return of wheat price

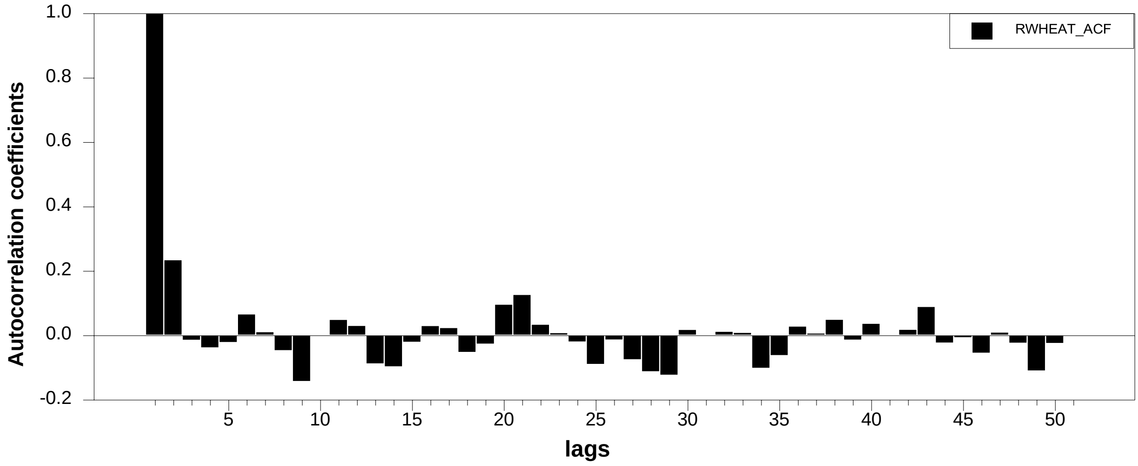


The analysis of the autocorrelation function (see figure 16) of the return of wheat price shows that, this series has a very short memory like the return of rice price. The current value of the return of wheat price is affected only by its past 2 month's value.

In connection with this result, the spectral analysis of this price return (see figure 15) shows that the main frequencies are at 1.16, 1.69 and 2.26 which correspond respectively to a time period of 5.4 months, 3.7 months and 2.78months.

The return of wheat price has a short term cycle with a duration of 2 to 5 months. Like for rice, if a shock on this return is observed today, it will last for 2 to 5 months before we can observe another shock.

Figure 16: ACF OF THE PRICE RETURN OF WHEAT

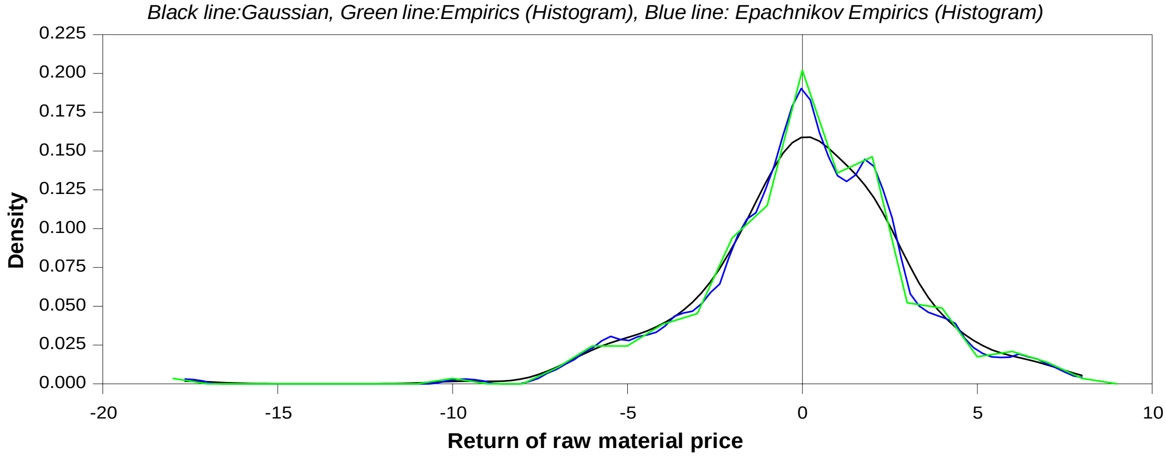


- **The return of Agricultural Raw material price**

The figure 17 shows that the empirical distribution of the return of agricultural raw material price don't follow a Gaussian (normal) distribution, bust instead follow an Epachenikov distribution. The Epachenikov distribution fit quit well the empiric one. We can also see that the return of agricultural raw material price has a fat tail and is skewed on the left, which confirm the results found in table 1.

Figure 17: Distribution of the return of raw material price

Black line:Gaussian, Green line:Empirics (Histogram), Blue line: Epachnikov Empirics (Histogram)



The analysis of the autocorrelation function (see figure 19) of the return of agricultural raw material price shows that, this series has a short memory but longer than the previous returns prices. The current value of this return is affected only by its past 5 to 10 month's values.

The spectral analysis of this price return (see figure 18) shows that the main frequencies are at 0.534 and 1.92 which correspond respectively to a time period of 11.76 months and 3.28 months.

Figure 18: Periodogram of the return of agricultura raw material price

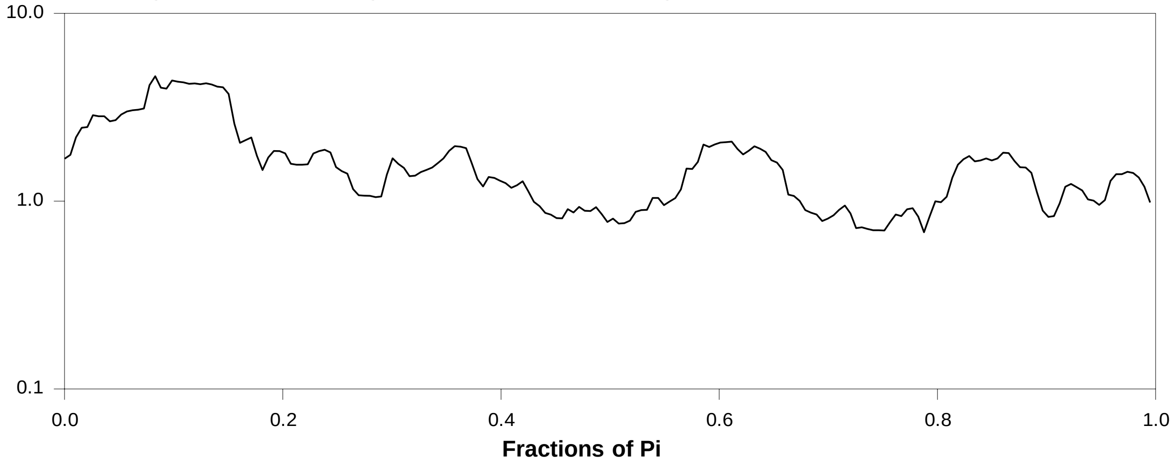
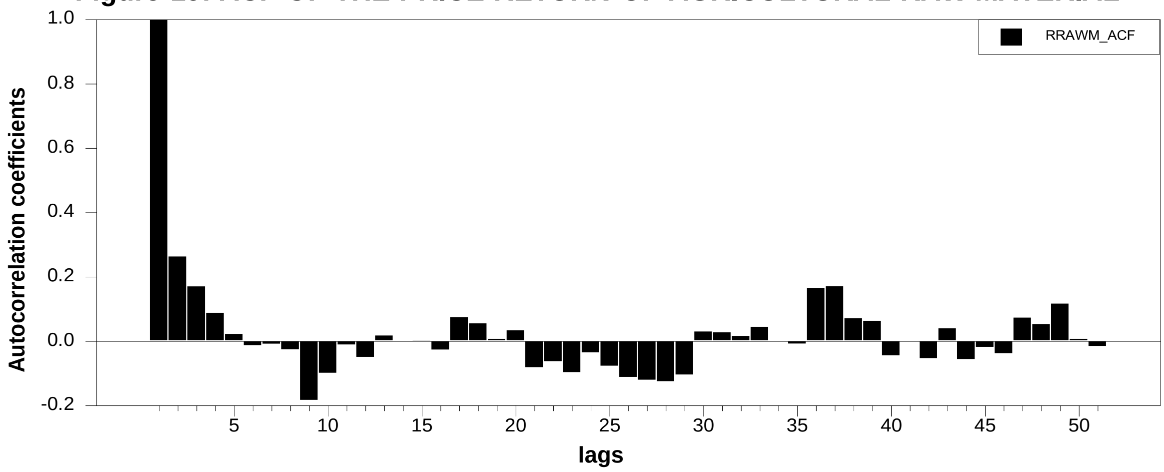


Figure 19: ACF OF THE PRICE RETURN OF AGRICULTURAL RAW MATERIAL



The return of agricultural raw material price has a short term cycle with a duration of 3-11 months, which is quit longer than the duration of the previous series. A shock on this return will last for 3 to 11 months before we can observe another shock.

- **The return of metal price**

Like for the 5 previous cases, the empirical distribution of the return of metal price don’t follow a Gaussian (normal) distribution, bust instead follow an Epachenikov distribution. The Epachenikov distribution fit quit well the empiric one. Also this return has a fat tail and is skewed on the left, which confirm the results found in table 1.

The analysis of the autocorrelation function (see figure 22) of the return of metal price shows that, this series has a long memory in comparison with the previous returns prices. The current value of this return is affected by its past 5 to 10 month's values.

In connection with this result, the spectral analysis of this price return (see figure 21) shows that the main frequencies are at 0.2512, 0.8164, and 1.507 which correspond respectively to a time period of 2 years, 7 months and 4 months. The return price of metal exhibit two cycles: a short-term cycle with a duration of 4 to 7 months, and a long term cycle with a duration of 2 years.

Figure 20: Distribution of the return of metal price

Black line:Gaussian, Green line:Empirics (Histogram), Blue line: Epachnikov

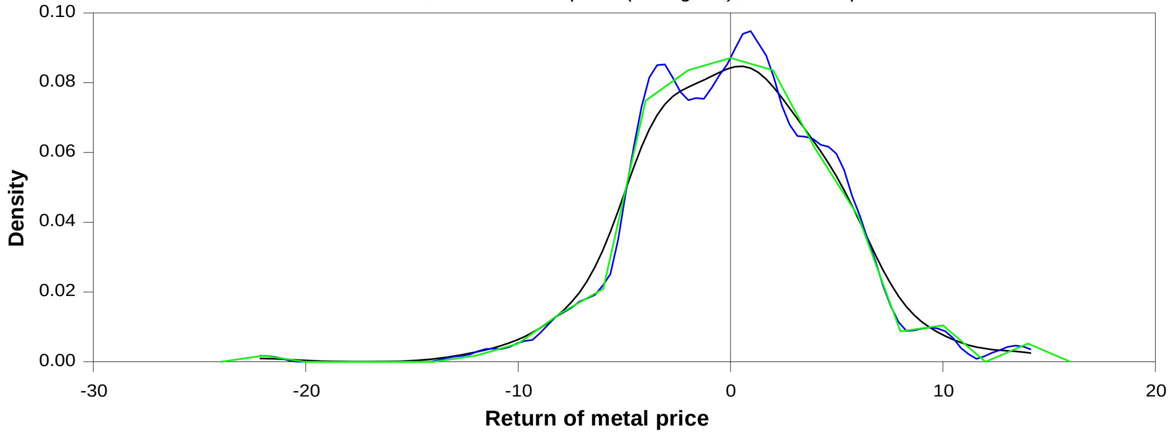


Figure 21: Periodogram of the return of metal price

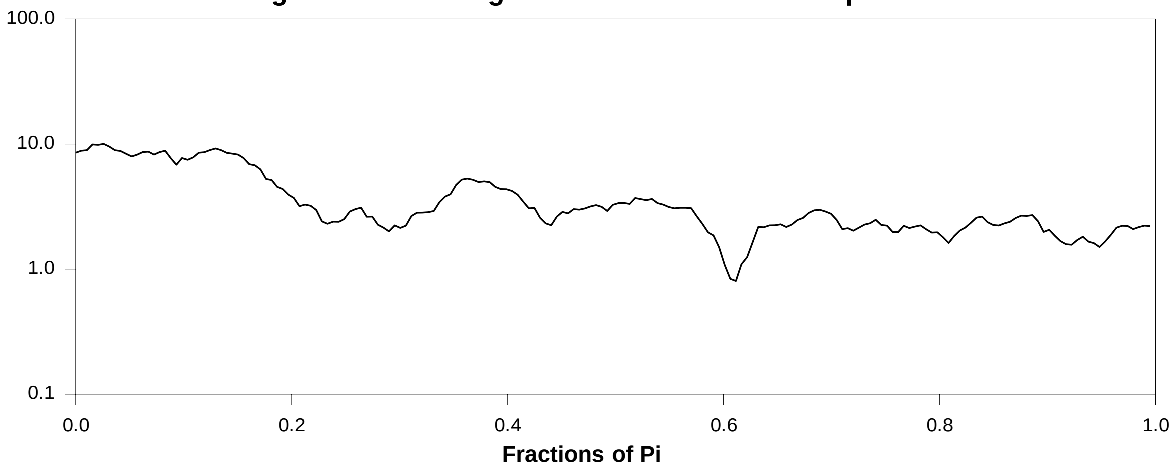
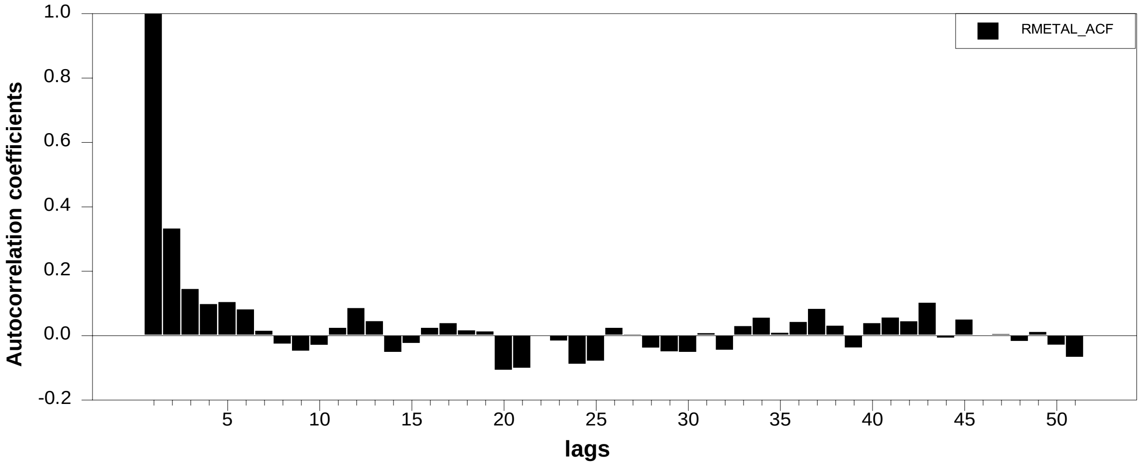


Figure 22: ACF OF THE PRICE RETURN OF METAL



I-3 ENSO shocks impact on the return of commodities prices

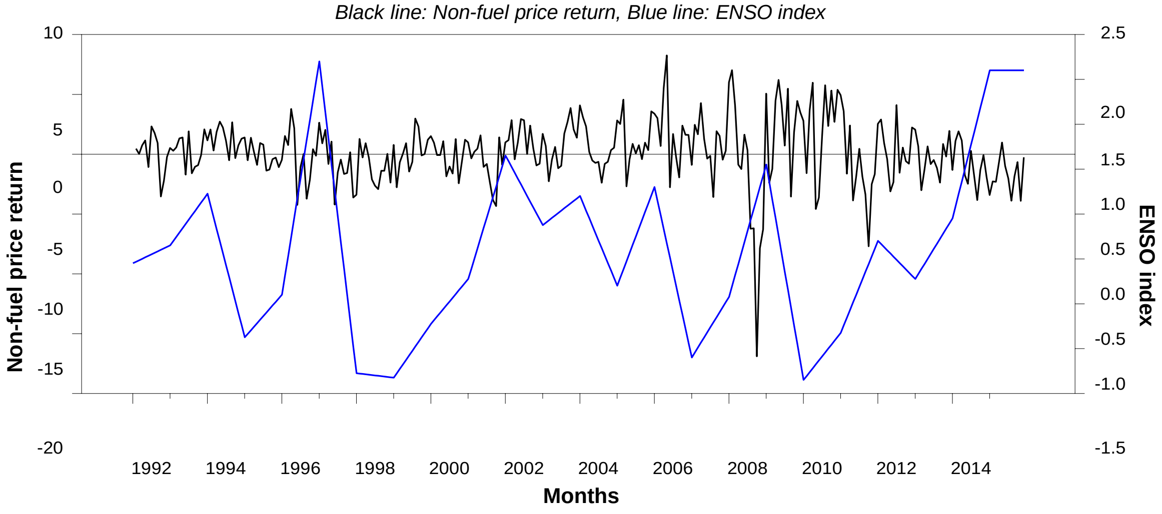
In this section, we will try to assess the impact of extremal temperatures conditions on the return price of each commodity. For this purpose, we will use two econometrics methods: a non-parametric regression approach and a co-spectral analysis in the frequency domain approach. The first one will help us to see if the return of the commodities prices are influenced by El Nino or La Nina. This approach assume that the predictor (ENSO index) does not take a predetermined form but is constructed according to information derived from the data. In this study we use a kernel regression method. The second approach belong to the frequency domain analysis, and will help us to analyze the cross-correlation between the two time series during the period 1992-2015.

Analyzing the impact of ENSO shocks on the price trend is another interesting point to make when assessing the impact of extreme climatic conditions on commodities prices. The price trends are computed using 10 months moving average filters. It is useful to see, if the prices have an increasing trend or not on average during a time period.

1. ENSO shocks impact on the return of non-fuel price

From the figure 23, it's hard to see if the ENSO index and the return of non-fuel price are correlated. However, we can see that, the lowest values of this return are associated to El Nino episode (ENSO index is above +0.5). The 2008-2009 period is a good example. Also it's hard to say if this relationship between the two time series is contemporaneous or if it is characterized by a lead or lag of one series on another. This situation gives a good justification for the use of a non-parametric regression and a co-spectral analysis.

Figure 23: Non Fuel price return and extremal temperature conditions

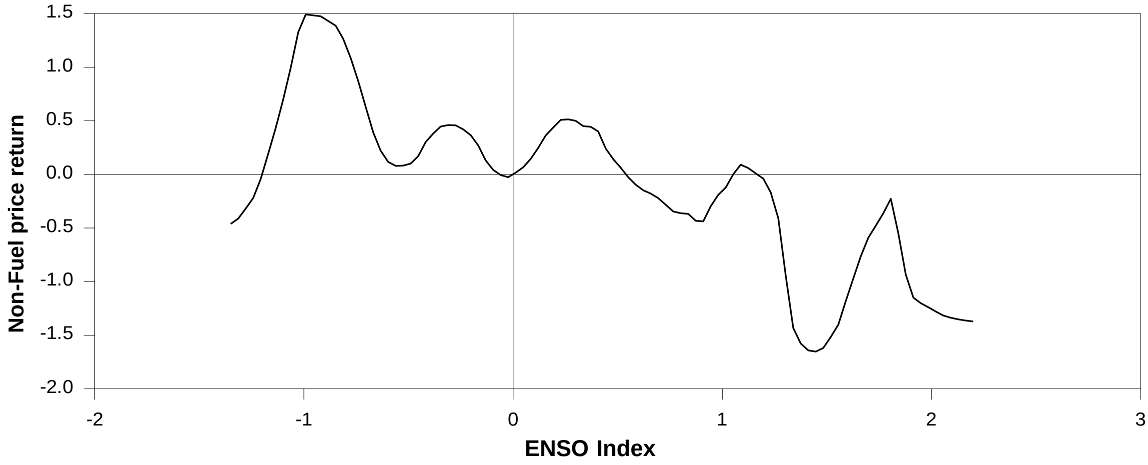


The results of the kernel regression between the ENSO index and the return of non-fuel price are presented in the figure 24. As on can see from this figure, the relationship between the two time series is not linear nor stable. In fact, it is variable according to the level of ENSO index. From this figure, we can say that the two series are correlated and the shocks on ENSO index affect the return of non-fuel price. El Nino episodes have a negative impact on this return, its lowest value (-1.5%) is associated to a high value (1.5: "strong El Nino") of ENSO index. After an El Nino episode investors should bet on a decline of the return of non-fuel price.

We can also see that La Nina has a positive effect on the return of non-fuel price. A weak La Nina episode (ENSO index below -0.5 to -0.9) is correlated with a high value of this return (1.5%). However, this effect could be negative in the presence of a strong episode of La Nina. In this case, the return of non-fuel price decreases but still have a positive sign.

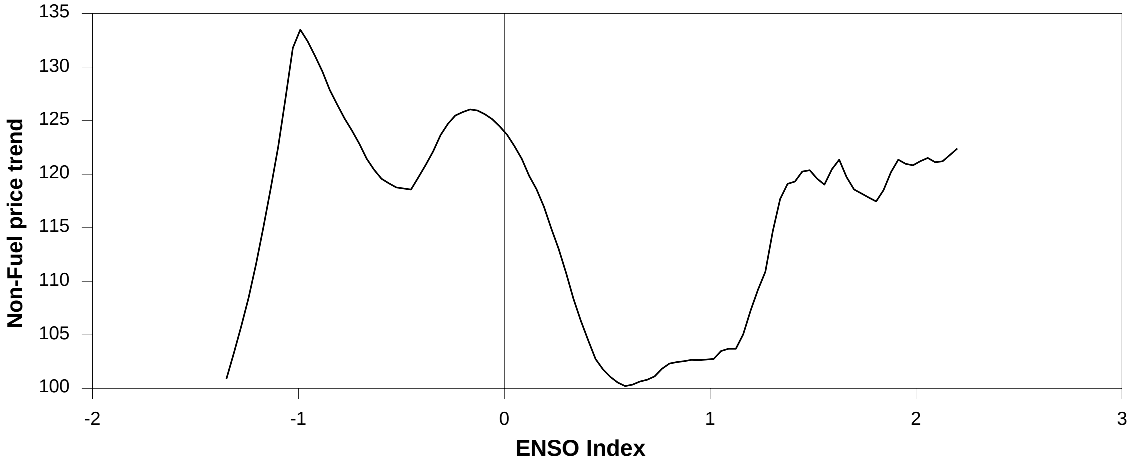
In others words, El Nino episodes are associated with negative values of the return, while La Nina is associated to its positive values. Therefore, it may be a good idea to sell non-fuel assets after La Nina episodes.

Figure 24: Kernel regression : Climatic changes impact on non-fuel price return



From the figure 25, one can see that ENSO shocks have an effect on the trend of non-fuel price. On average, El Nino episodes are associated to a rising trend, while La Nina episode are associated to a falling trend.

Figure 25: Kernel regression : Climatic changes impact on non-fuel price trend



The series of figures 26 (a, b, c, and d) show the result of the co-spectral analysis between the ENSO index and the return of non-fuel price.

From figure 26a, one can see that the cospectrum has high values and negative sign at low frequencies, while at high frequencies its values is near 0 and is positive. This suggests that the ENSO index and the return of non-fuel price have long-term relationship and are negatively correlated, which confirms the result of the non-parametric regression.

Figure 26a: Cospectrum ENSO index and non-fuel price return

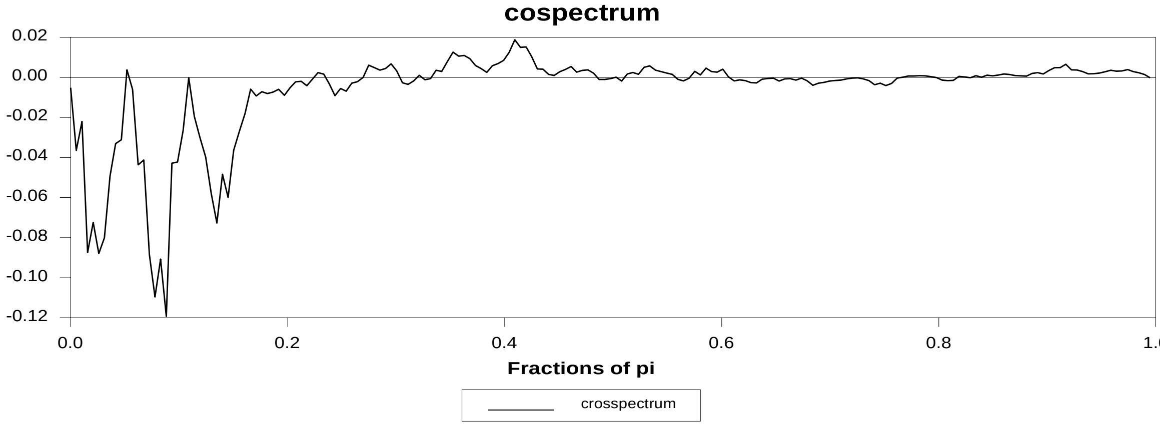


Figure 26b: Coherence ENSO index and non-fuel price return

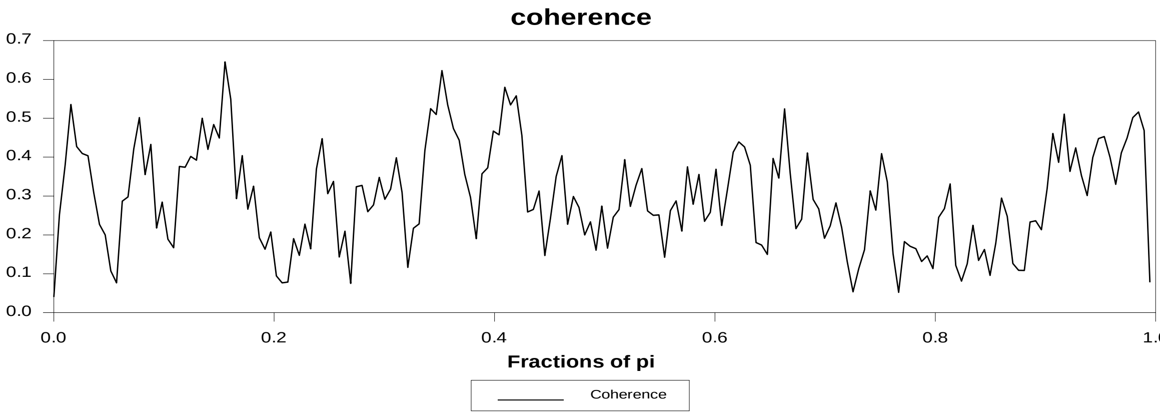
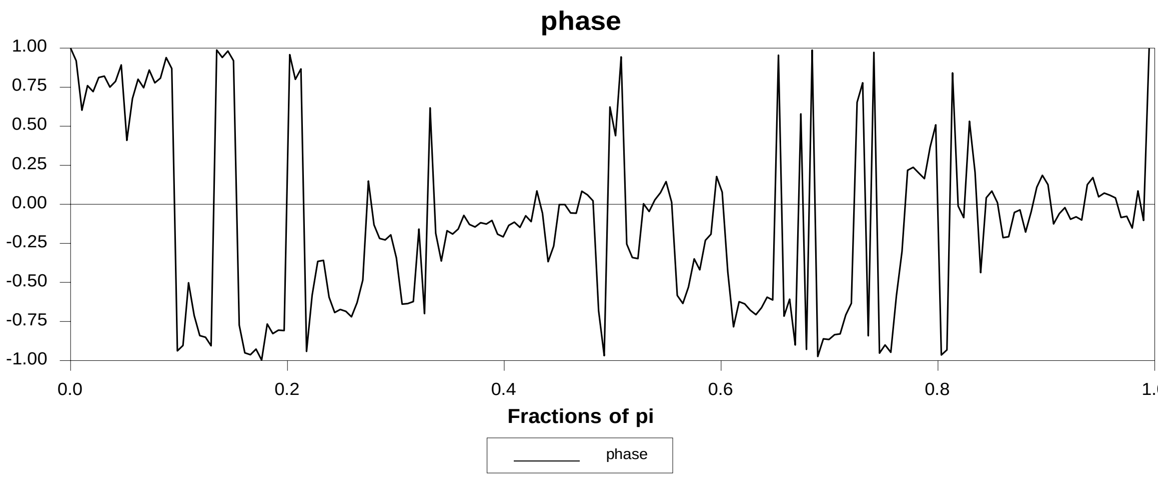


Figure 26c: Phase ENSO index and non-fuel price return



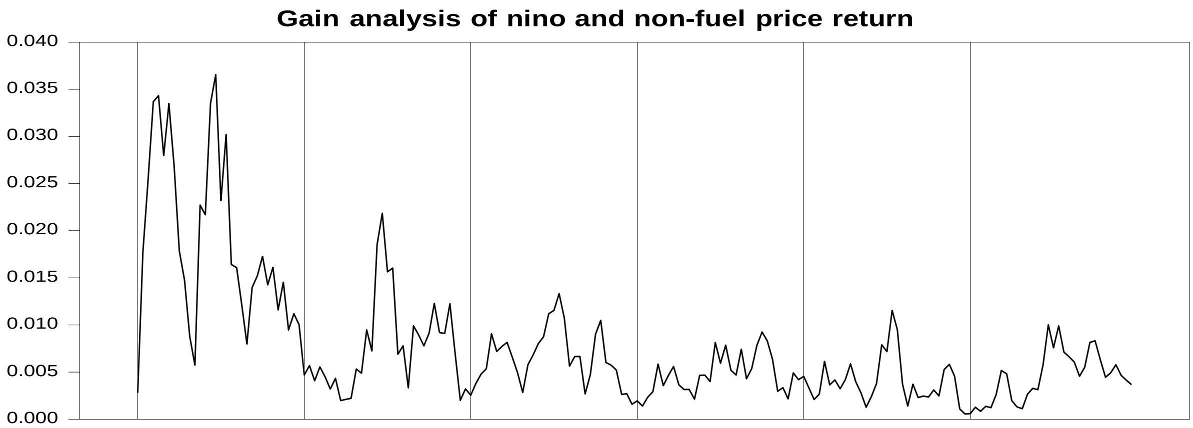
The intensity of the correlation between these two series is given by the coherence graph (figure 26b). For the entire period of analysis, the coherence lies between 0.1 and 0.6. The high values of the coherence are observed at low frequencies, suggesting a high correlation between the two time series at these frequencies. This confirm the results find in figure 26a.

At low frequencies, the phase fluctuate between positive and negative values. The phase diagram (figure 26c) indicates which of two series take the lead. A positive value of the phase means that the ENSO shocks has an effect on the return of non-fuel price.

The significant pics of the cospectrum correspond to the frequencies of 0.242 and 0.276. At these frequencies, the values of the coherence are respectively equal to 0.5 and 0.43, and the corresponding values of the phase are respectively, 0.77 and 0.94. Therefore, we can say that, the long-term relationship between ENSO index and the return of non-fuel price has a duration of 1.89-2.16 years. Also the return of non-fuel price lead the ENSO index by 3.18 to 3.4 months.

In others words, within a long-term relationship of 1 to 2 years, a shock on ENSO index affect negatively the return of non-fuel price after 3 months. The figure 26d, tells us that, the amplitude of this impact lies between 0.03% and 0.04% after 3 months. For example, El Nino has a negative impact on palm production especially in Indonesia (leader in palm oil production), which in turn affect the palm oil production and the prices.

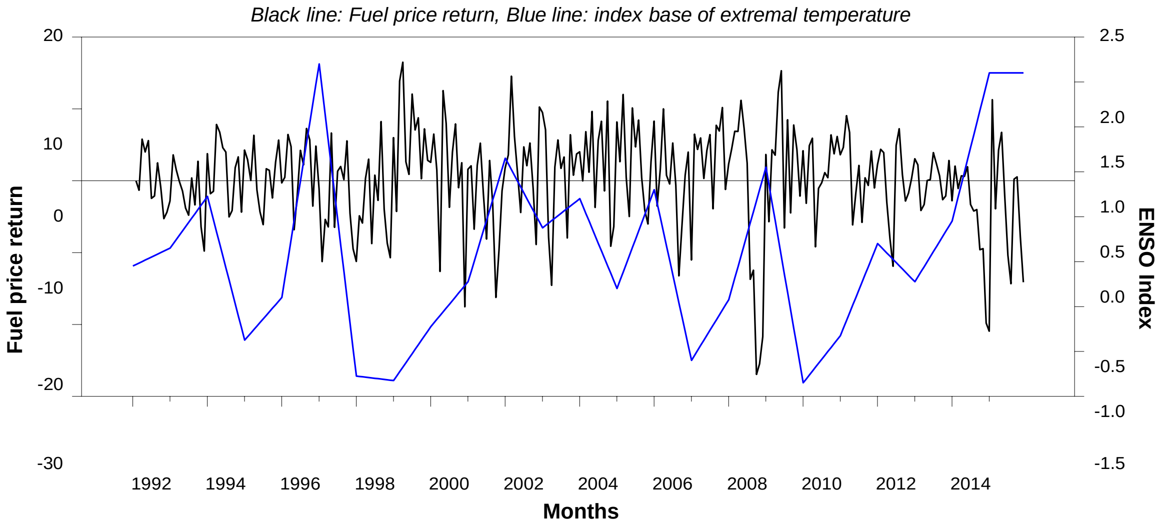
Figure 26d: Gain ENSO index and non-fuel price return



2. ENSO shocks impact on the return of fuel price

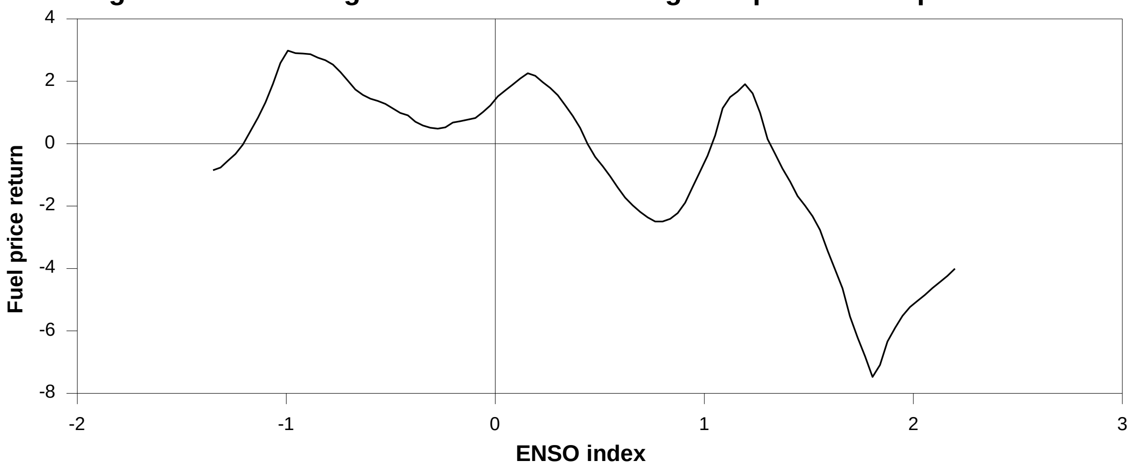
Even if it’s hard to see if the ENSO index and the return of fuel price are correlated. The figure 27, shows that the lowest values of this return are associated to El Nino episodes (ENSO index is above +0.5). The 1996-1997 and 2008-2009 periods are good examples. Also it’s hard to better describe the relationship between the two time series, which justify the use of the non-parametric regression and a co-spectral analysis, like in the previous case.

Figure 27: Fuel price return and extremal temperature conditions



The results of the kernel regression between the ENSO index and the return of fuel price are presented in the figure 28. This results are equivalent to what we found for the return of non-fuel price. The relationship between the two time series is not linear and vary according to the level of ENSO index. From this figure, we can say that the two series are correlated and the shocks on ENSO index affect the return of fuel price. El Nino episodes have a negative impact on this return, its lowest value (-8%) is associated to a high value (near 2: "strong El Nino") of ENSO index. After an El Nino episode investors should bet on a decline of the return of fuel price.

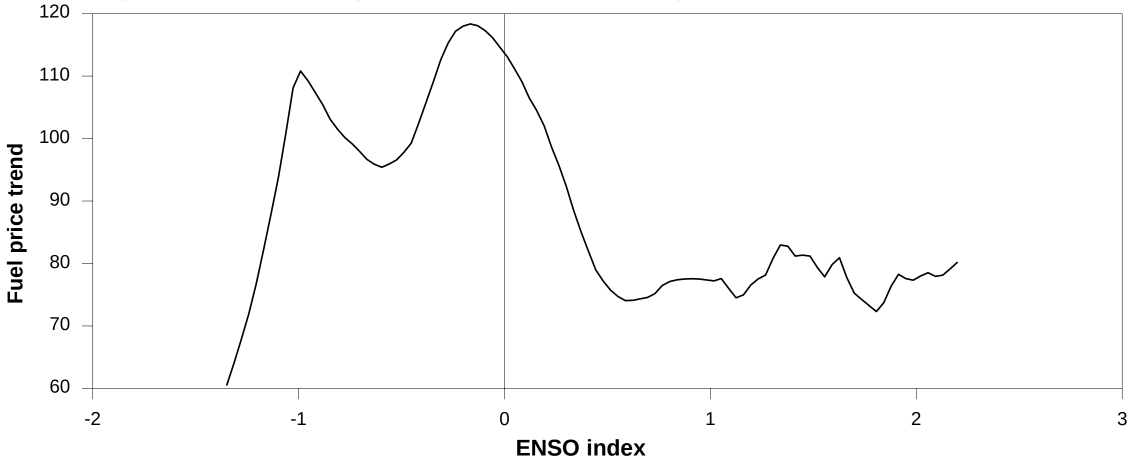
Figure 28: Kernel regression : Climatic changes impact on fuel price return



We can also see that La Nina has a positive effect on the return of fuel price. Even if this impact is moderate, a weak La Nina episode (ENSO index below -0.5 to -0.9) is correlated with positives values of this return (up to 2%). However, this effect could be negative in the presence of a strong episode of La Nina. In that case, the return of fuel price decrease slightly before reaching a null value.

Figure 29 shows that the impact ENSO on the trend of fuel price comes from La Nina episodes. In fact, El Nino episodes don't affect significantly this trend. On average, La Nina episodes are associated to a falling trend.

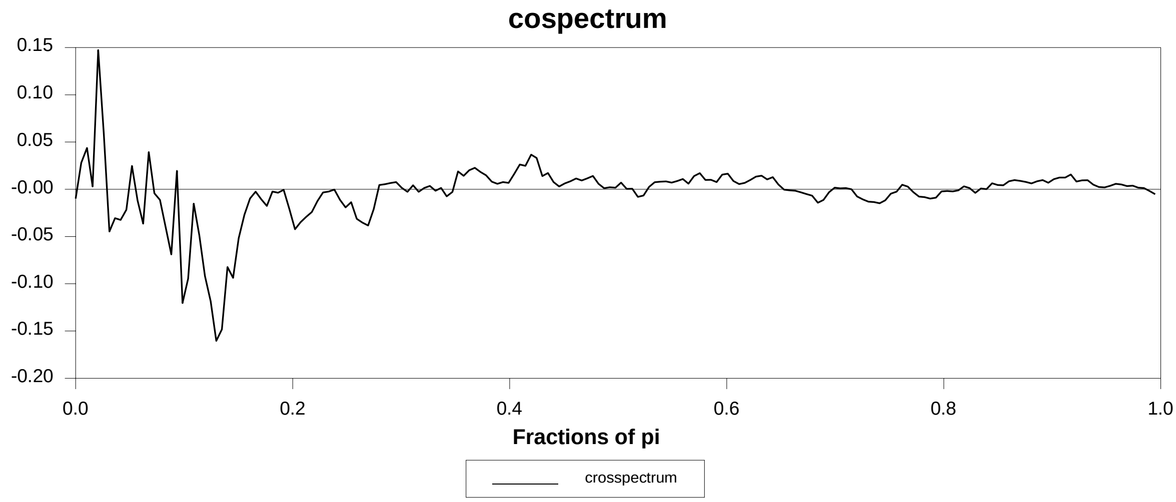
Figure 29: Kernel regression : Climatic changes impact on fuel price trend



The series of figures 30 (a, b, c, and d) give the results of the co-spectral analysis between the ENSO index and the return of fuel price.

From the figure 30a, one can see that the cospectrum has high values at low frequencies, while at high frequencies its values is near 0 and are positive. Also at the low frequencies, the cospectrum alternate between positive and negative values. This suggests that the ENSO index and the return of fuel price have long-term relationship and may be alternatively positively or negatively correlated.

Figure 30a: Cospectrum ENSO index and fuel price return



The intensity of the correlation between these two series lies between 0.1 and 0.7 (see figure 30b). At low frequencies the value of the coherence don't exceed 0.6, suggesting a moderate correlation between the two time series at these frequencies. This confirm the results find in figure 30a. However, a high coherence is also observed at high frequencies, which may suggest a strong relationship between this two series in the short-run. In connection with the above results, we will only consider the relationship at low frequencies.

Figure 30b: Coherence ENSO index and fuel price return

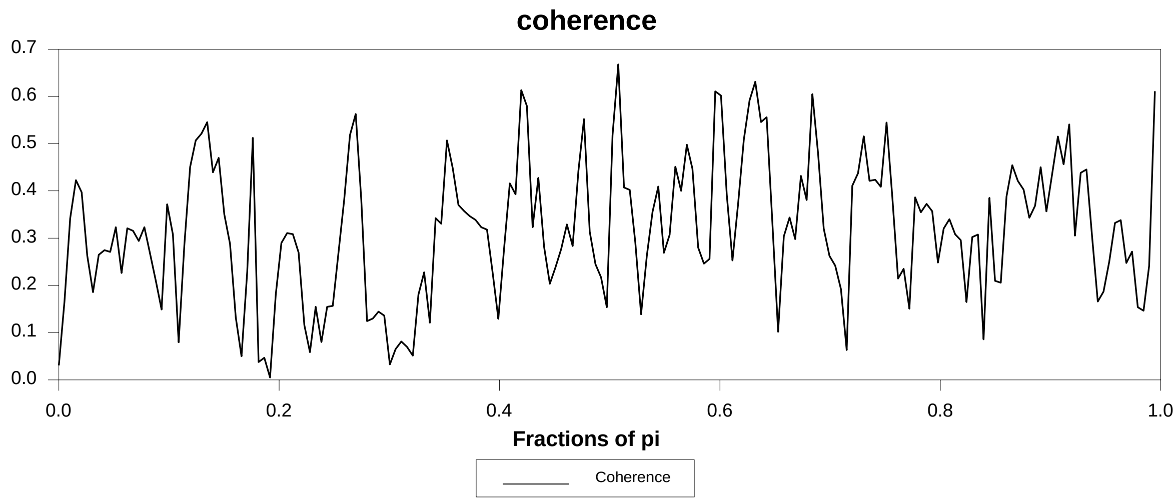
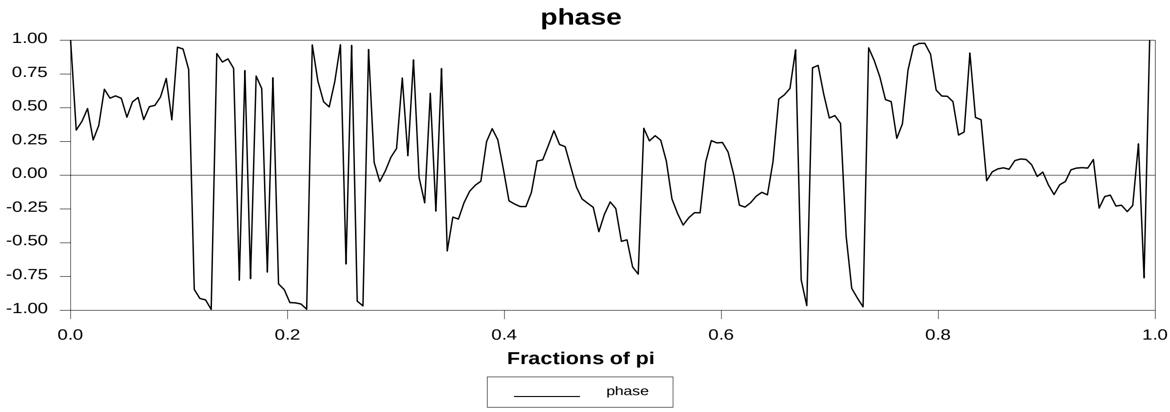


Figure 30c: Phase ENSO index and fuel price return

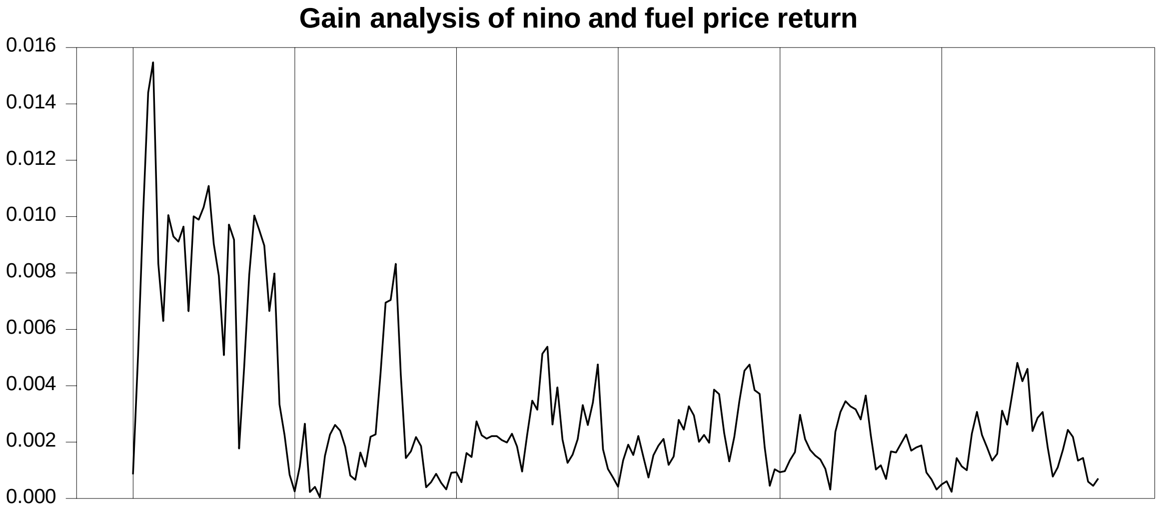


At low frequencies the phase fluctuate between positive and negative values (figure 30c), but it is mostly positive. A positive value of the phase means that the ENSO shocks has an effect on the return of fuel price.

The significant pics of the cospectrum are observed at the frequencies of 0.066 (corresponding to a positive value of the cospectrum) and 0.4239 (corresponding to a negative value of the cospectrum). At these frequencies, the values of the coherence are respectively equal to 0.39 and 0.55, and the values of the phase are respectively, 0.26 and 0.90. The first frequency is too low to be plausible and also the corresponding value of the coherence is lower in comparison to that of the second frequency. Therefore, we can say that, the long-term relationship between ENSO index and the return of fuel price has a duration of 1.23 years. Also the return of fuel price lead the ENSO index by 2.12 months.

In others words, within a long-term relationship of 1 year and 3 months, a shock on ENSO index affect negatively the return of fuel price after 2 months. The figure 30d, tells us that, the amplitude of this impact is 0.008% after 2 months.

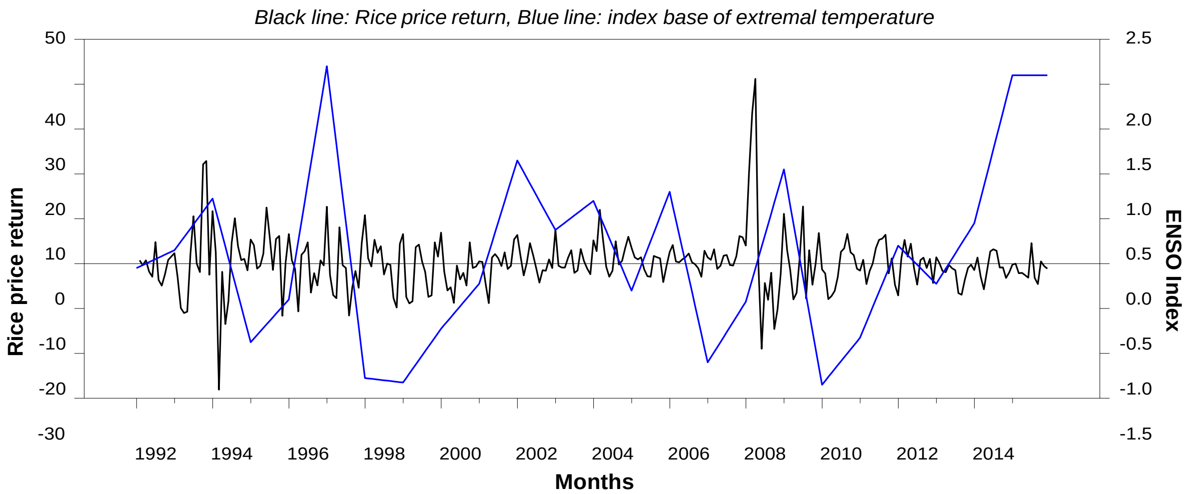
Figure 30d: Gain ENSO index and fuel price return



3. ENSO shocks impact on the return of rice price

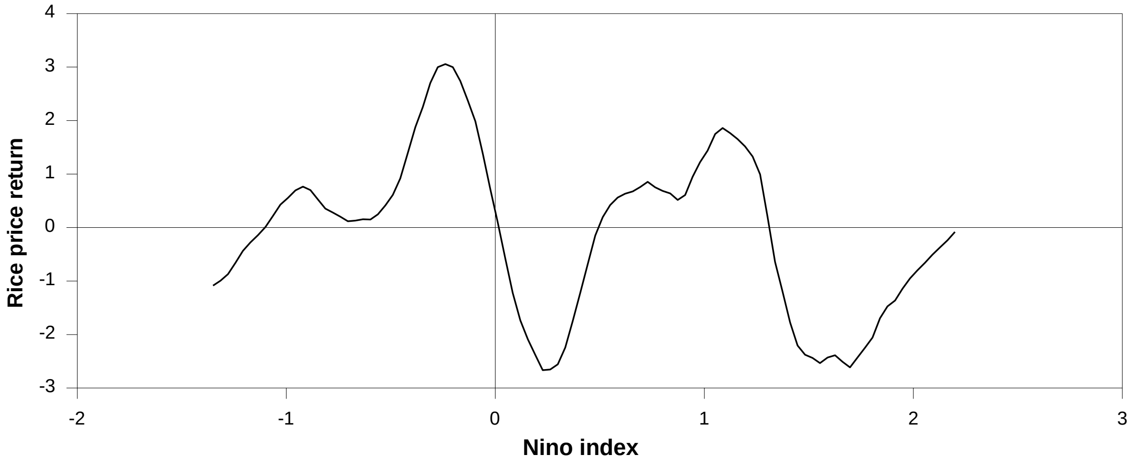
As for the previous cases, on can see that it's hard to see if the ENSO index and the return of rice price are correlated. The figure 31, shows that the lowest values of this return may be associated to El Nino episodes. The 1996-1997 period is a good example. Also it's hard to better describe the relationship between the two time series (is it a lead-lag relationship?), which justify the use of the non-parametric regression and a co-spectral analysis, like in the previous cases.

Figure 31: Rice price return and extremal temperature conditions



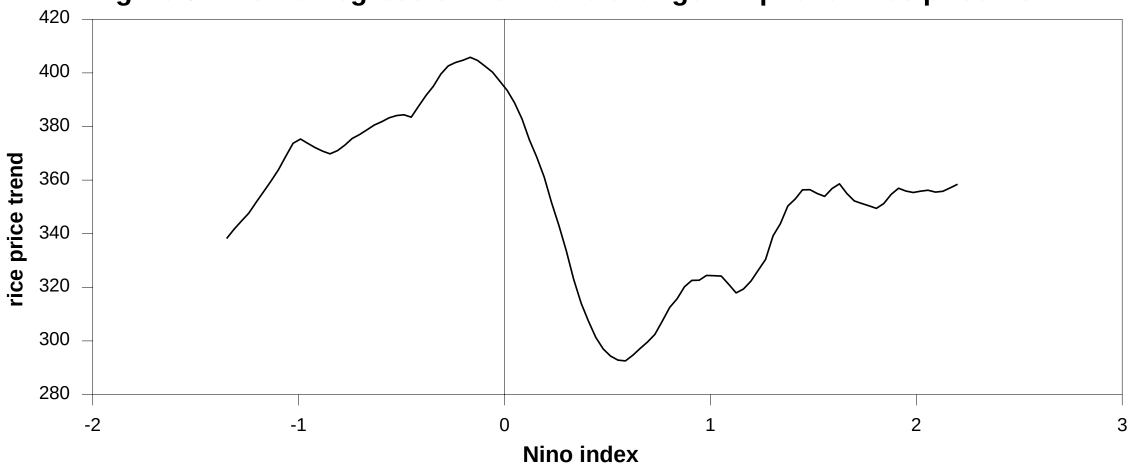
The kernel regression between the ENSO index and the return of rice price (figure 32) shows that, the relationship between the two times series vary more in comparison to previous cases. From this figure, we can say that the two series are correlated and the shocks on ENSO index affect the return of rice price. However, it is mostly El Nino episodes that effect this return. Its effect on the return of rice price is much nuanced. A weak El Nino is slightly correlated to positive values of this return. And a moderate El Nino episode has a negative impact on it, while a strong El Nino episode tend to have a positive impact on it. The position of investors after an El Nino episode should therefore depend on its intensity.

Figure 32: Kernel regression : Climatic changes impact on rice price return



From the figure 32 we can see that the impact of ENSO on the trend of rice price is positive for El Nino episodes and negative for La Nina episodes. El Nino episodes affect significantly this trend. On average, La Nina episodes are associated to a falling trend.

Figure 32: Kernel regression : Climatic changes impact on rice price trend



From the figure 33a, one can see that the cospectrum has high positive values at low frequencies, while at high frequencies its values is near 0 and is positive also. This suggests that the ENSO index and the return of rice price have long-term relationship and may be positively correlated.

The intensity of the correlation between these two series lies between 0.1 and 0.7 (see figure 33b). At low frequencies the value of the coherence don't exceed 0.4, suggesting a moderate correlation between the two time series at these frequencies. This confirm the results find in figure 33a. However, a high coherence is also observed at high frequencies, which may suggest a strong relationship between this two series in short run. In connection with the above results, we will only consider the relationship at low frequencies.

Figure 33a: Cospectrum ENSO index and rice price return

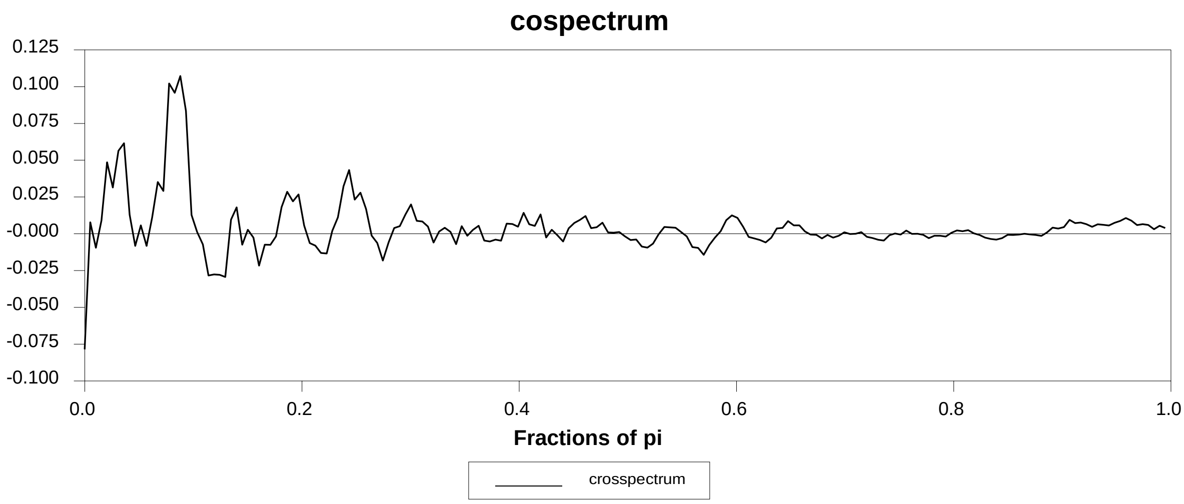
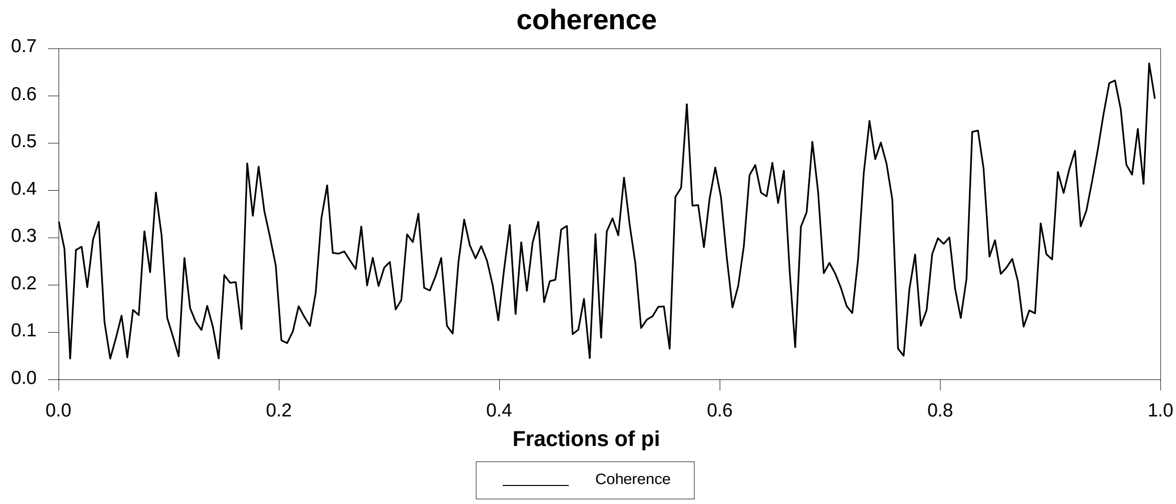


Figure 33b: Coherence ENSO index and rice price return



At low frequencies the phase fluctuate between positive and negative values (figure 33c), but is mostly positive. A positive value of the phase means that the ENSO shocks has an effect on the return of rice price.

The significant pics of the cospectrum is observed at the frequency of 0.276. At this frequency, the value of the coherence is equal to 0.39, and the value of the phase is 0.29.

Therefore, we can say that, the long-term relationship between ENSO index and the return of rice price has a duration of 2 years. Also the return of rice price leads the ENSO index by 1.05 months. The impact of ENSO shocks on the return of rice price is quite immediate, even if it is moderate.

In others words, within a long-term relationship of 2 years, a shock on ENSO index affect positively the return of rice price after 1 month. The figure 33d, tells us that, the amplitude of this impact is 0.02% after 1 month. In fact, ENSO shocks affect the countries who are leader in rice production (India, Pakistan, Thailand and Vietnam), where 60% of the world rice is grown. ENSO shocks (especially El Nino) have a negative impact on rice yield, which reduces the rice supply, and increases the rice price. This effect on rice, an annual crop whose production cycle lasts one year, may last for 2 years because the El Nino episodes last 9-12 months, and may impact the next year rice production.

Figure 33c: Phase ENSO index and rice price return

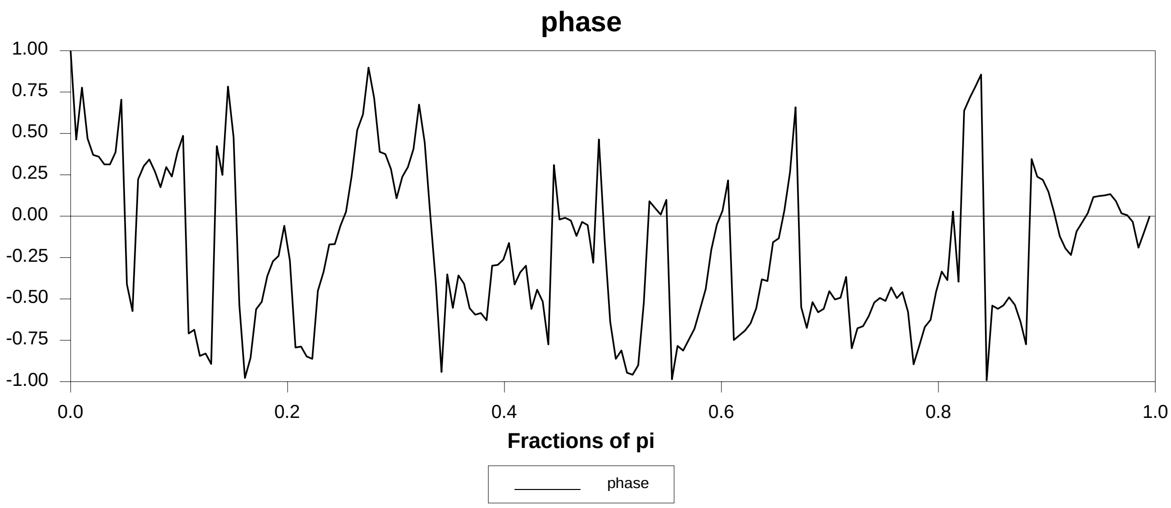
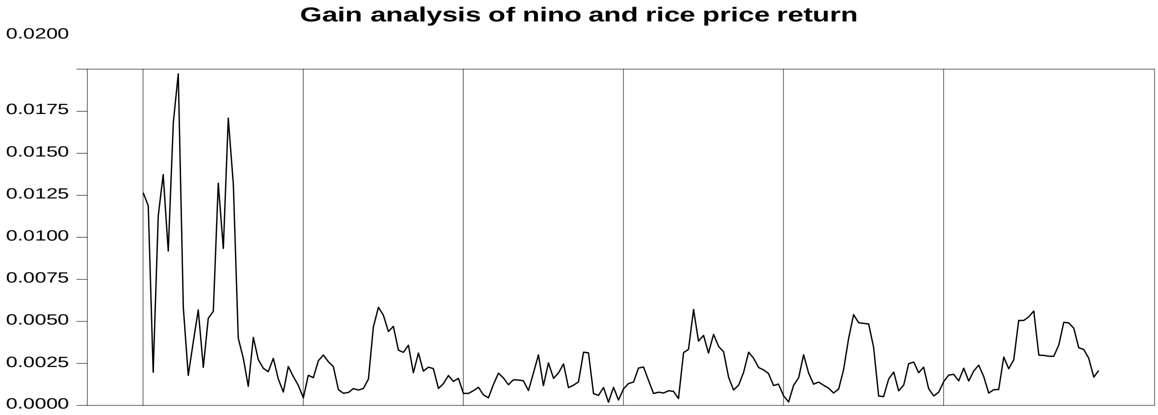


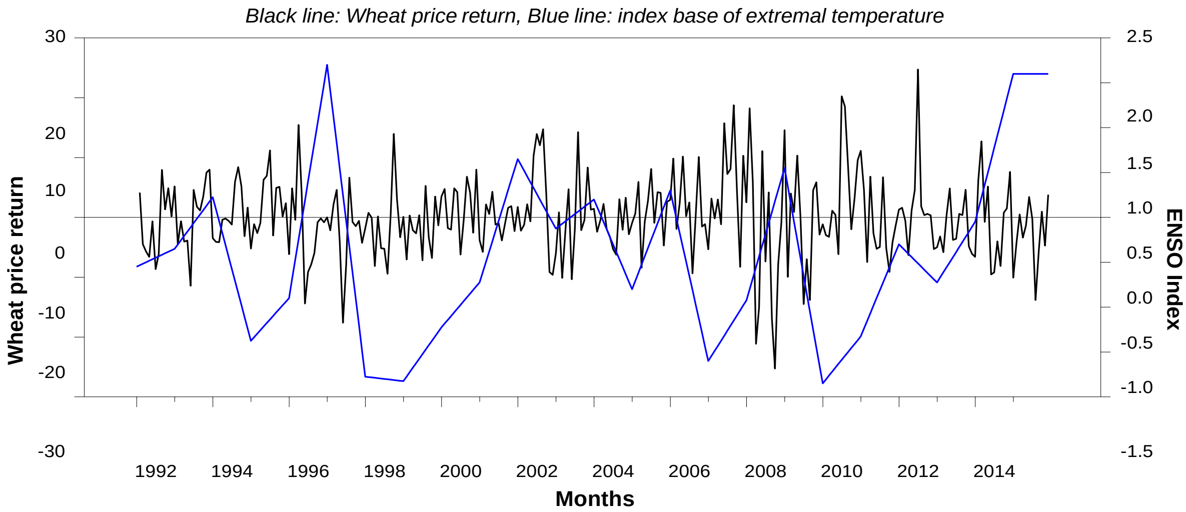
Figure 33d: Gain ENSO index and rice price return



4. ENSO shocks impact on the return of wheat price

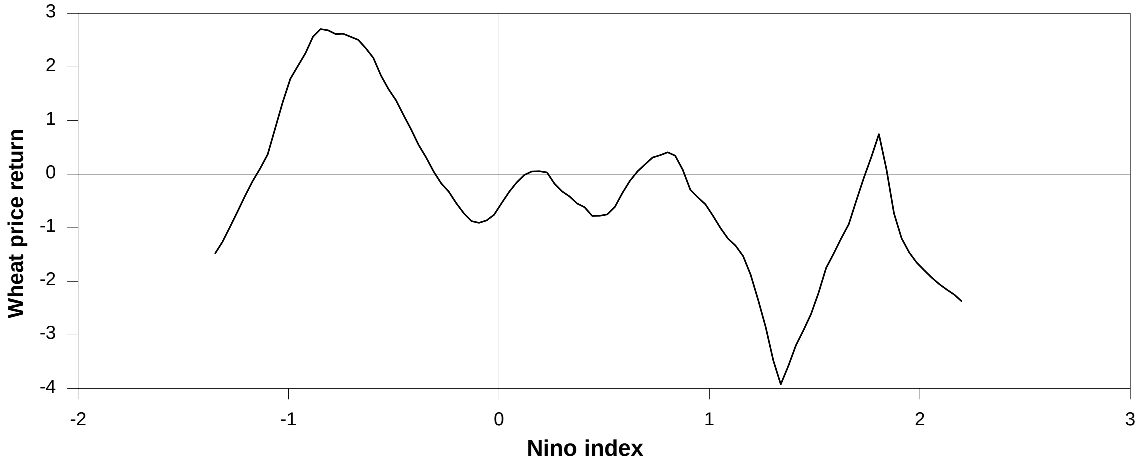
From figure 34 it's hard to see if the ENSO index and the return of wheat price are correlated. This figure shows that the lowest values of this return may be associated to El Nino episodes. However, it's hard to better describe the relationship between the two time series, which justify the use of the non-parametric regression and a co-spectral analysis, like in the previous cases.

Figure 34: Wheat price return and extremal temperature conditions



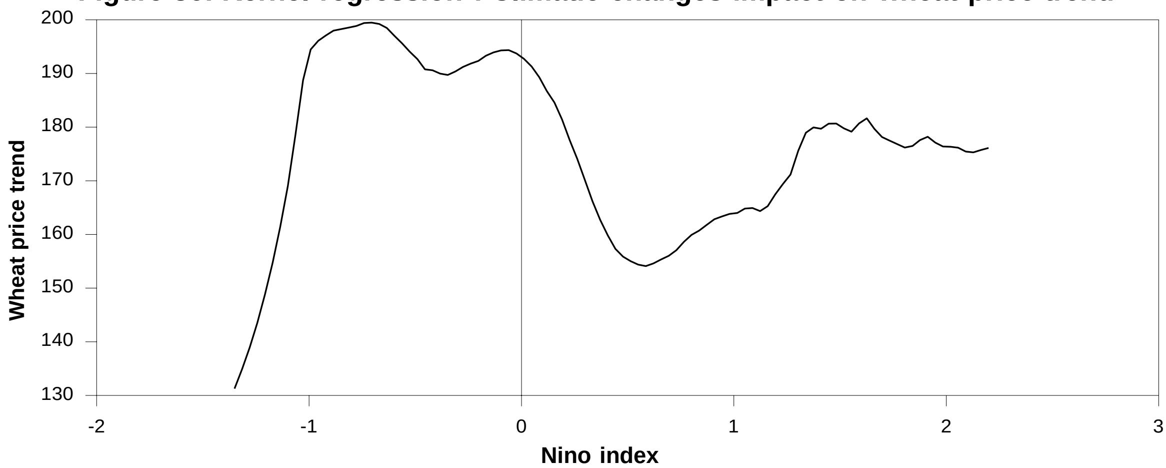
The kernel regression between the ENSO index and the return of wheat price (figure 35) shows that the two series are correlated. We can see that, negative returns of wheat price are associated to El Nino episodes, while La Nina episodes are mostly associated to positive values of this return. However, the effect of ENSO index on the return of wheat price is more nuanced. A weak El Nino is correlated positively to this return. And a moderate El Nino episode has a negative impact on it, while a strong El Nino episode tend to have a positive impact on it. The position of investors after an El Nino episode should therefore depend on its intensity, like for the rice case.

Figure 35: Kernel regression : Climatic changes impact on wheat price return



From the figure 36 we can see that the impact of ENSO on the trend of wheat price is positive for El Nino episodes and negative for La Nina episodes. El Nino episodes affect slightly this trend. On average, La Nina episodes are associated to a falling trend.

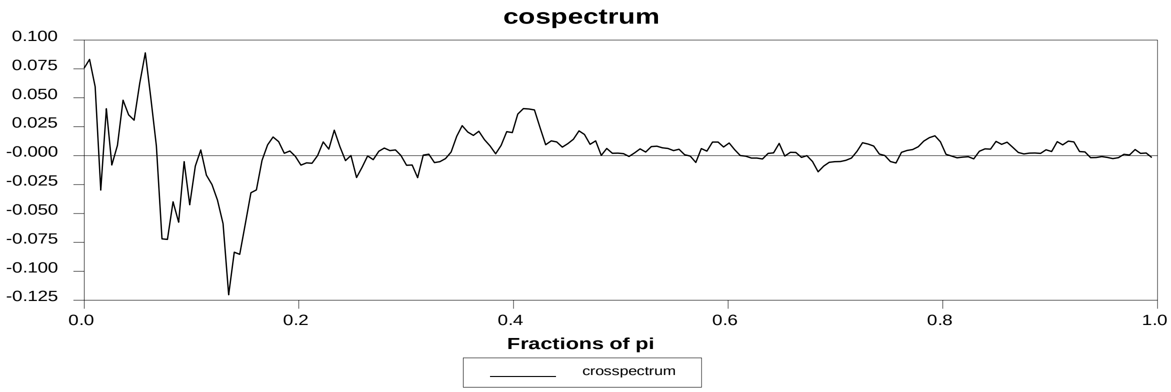
Figure 36: Kernel regression : Climatic changes impact on wheat price trend



From figure 37a, one can see that the cospectrum alternate between positives and negative values at low frequencies, while at high frequencies its values is near 0 and is most positive. This suggests that the ENSO index and the return of wheat price have a long-term relationship and may be positively or negatively correlated.

The intensity of the correlation between these two series lies between 0.1 and 0.7 (see figure 37b). At low frequencies the value of the coherence can reach 0.7, suggesting a strong correlation between the two time series at these frequencies.

Figure 37a: Cospectrum ENSO index and wheat price return

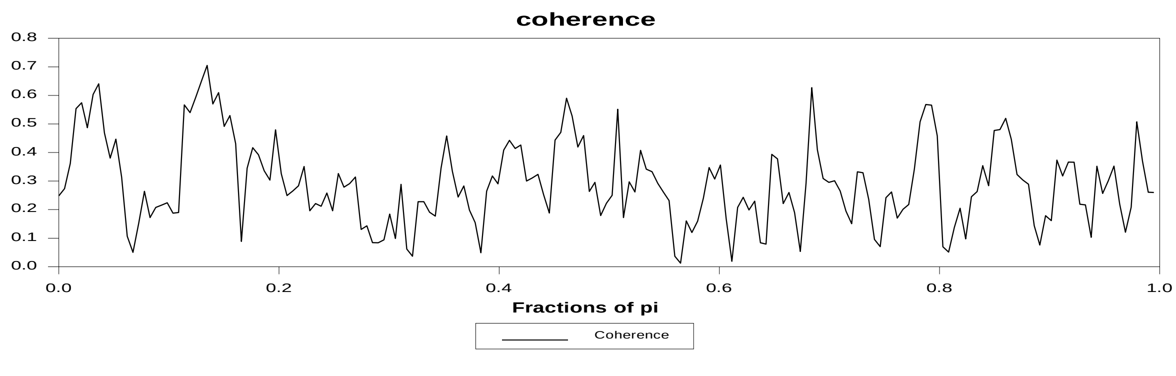


At low frequencies the phase fluctuate between positive and negative values (figure 37c), but is mostly positive. A positive value of the phase means that the ENSO shocks has an effect on the return of wheat price. We are mostly interested by the case where the phase is positive, because a negative phase mean a reverse causality between the two series. It is not expected that the return of wheat price could have an impact on ENSO index.

The significant pic of the cospectrum is observed at the frequency of 0.188. At this frequency, the value of the coherence is equal to 0.31, and the value of the phase is 0.17.

Therefore, we can say that, the long-term relationship between ENSO index and the return of wheat price has a duration of 2.77 years. Also the return of wheat price leads the ENSO index by 0.9 month almost 1 month. The impact of ENSO shocks on the return of wheat price is quite immediate, even if it is moderate.

Figure 37b: Coherence ENSO index and wheat price return



In others words, within a long-term relationship of 2 to 3 years, a shock on ENSO index affect positively (the value of the cospectrum is positive) the return of wheat price after 1 month. The figure 33d, tells us that, the amplitude of this impact is 0.01% after 1 month. These results are similar to those observed for rice.

Figure 37c: Phase ENSO index and wheat price return

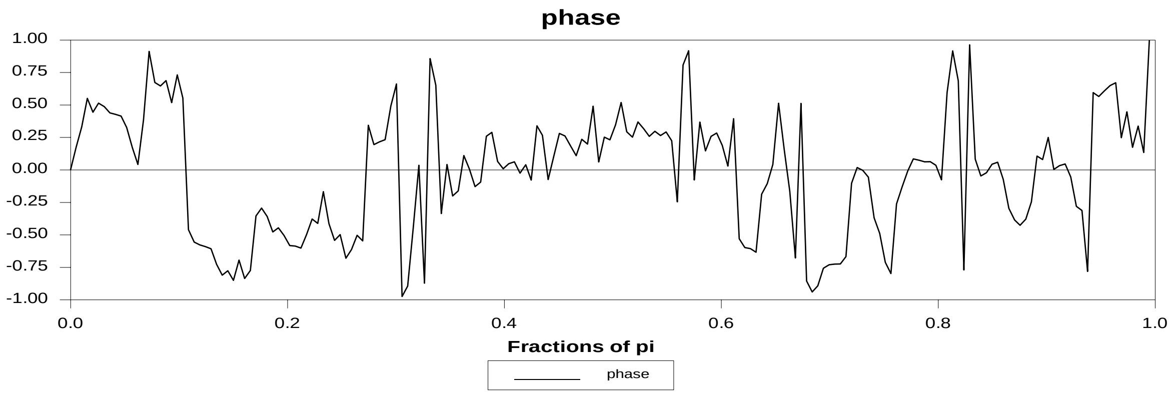
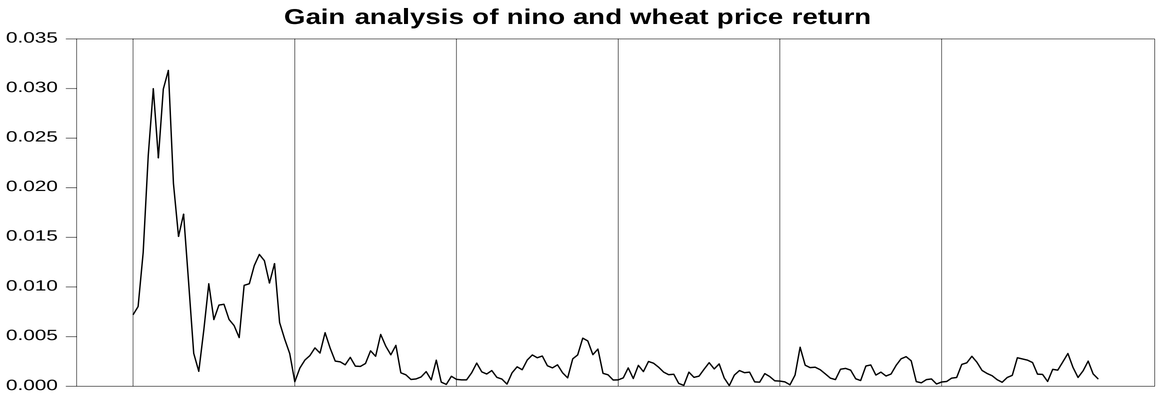


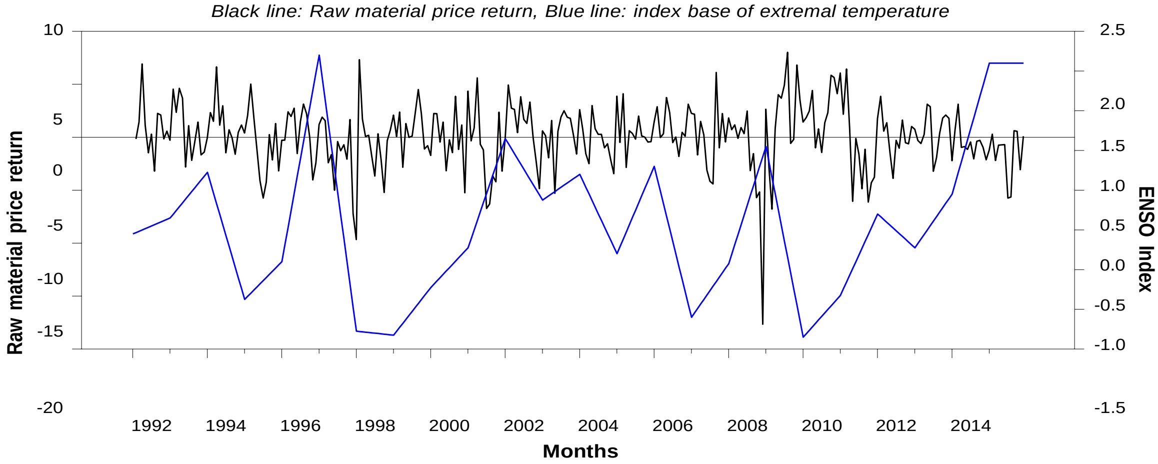
Figure 37d: Gain ENSO index and wheat price return



5. ENSO shocks impact on the return of agricultural raw materials price

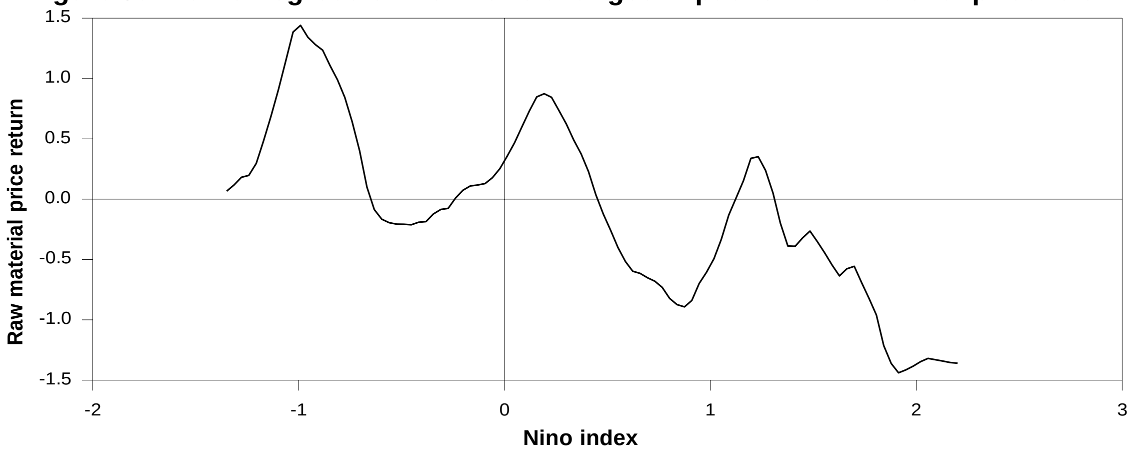
From the figure below it's hard to see if the ENSO index and the return of agricultural raw materials price are correlated. This figure shows that the lowest values of this return may be associated to El Nino episodes. Like in the previous cases, it's hard to better describe the relationship between the two time series, which justify the use of the non-parametric regression and a co-spectral analysis, like in the previous cases.

Figure 38: Raw materiel price return and extremal temperature conditions



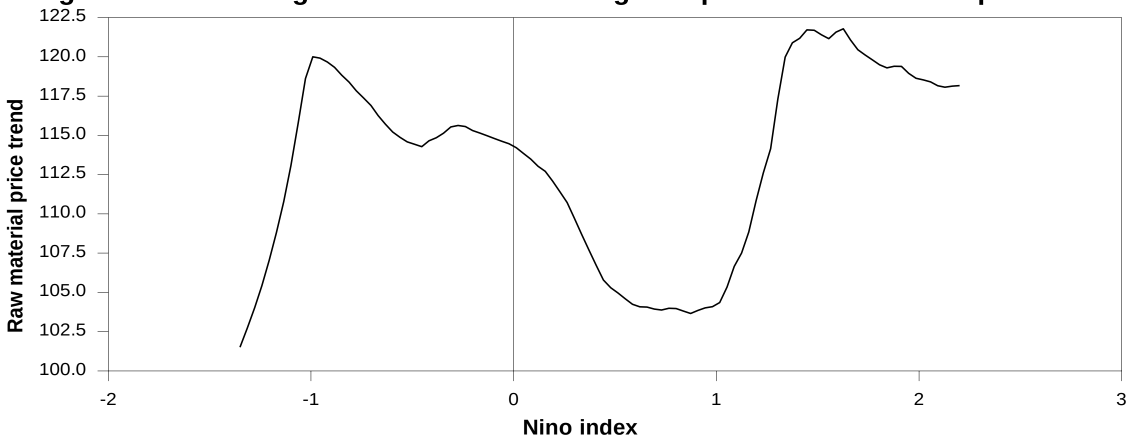
The kernel regression between the ENSO index and this return (figure 39) shows that the two series are correlated. We can see that, negative returns of agricultural raw materials price are associated to El Nino episodes, while La Nina episodes are mostly associated to positive values of this return. However, the effect of ENSO index on the return of agricultural raw materials price is more nuanced. A weak El Nino (La Nina) is positively correlated to this return. And a moderate El Nino (La Nina) episode has a negative impact on it. The position of investors after an El Nino episode should therefore depend on its intensity, like for the previous cases.

Figure 39: Kernel regression : Climatic changes impact on raw material price return



From figure 40 we can see that the impact of ENSO on the trend of agricultural raw materials price is positive for El Nino episodes and negative for La Nina episodes. El Nino episodes affect significantly this trend. On average, La Nina episodes are associated to a falling trend.

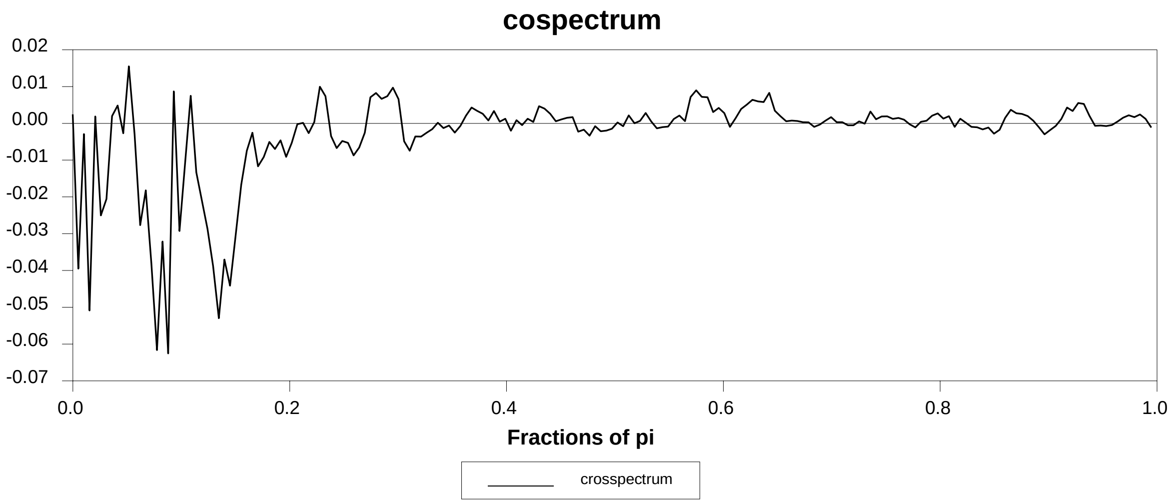
Figure 40: Kernel regression : Climatic changes impact on raw material price trend



From figure 41a, one can see that the cospectrum has most of the time a negative values at low frequencies, while at high frequencies its values is near 0 and is mostly positive. This suggests that the ENSO index and the return of agricultural raw materials price have a long-term relationship and may be negatively correlated.

The intensity of the correlation between these two series lies between 0.1 and 0.6 (see figure 41b). At low frequencies the value of the coherence don't exceed 0.5, suggesting a moderate correlation between the two time series at these frequencies.

Figure 41a: Cospectrum ENSO index and agricultural raw material price return



At low frequencies the phase fluctuate between positive and negative values (figure 41c), but is mostly positive. A positive value of the phase means, here also, that the ENSO shocks has an effect on the return of agricultural raw material price.

The significant pic of the cospectrum is observed at the frequency of 0.242. At this frequency, the value of the coherence is equal to 0.45, and the value of the phase is 0.64.

Therefore, we can say that, the long-term relationship between ENSO index and the return of agricultural raw material price has a duration of 2.16 years. Also this return leads the ENSO index by 2 to 3 months. The impact of ENSO shocks on this return is not immediate, and is moderate.

Figure 41b: Coherence ENSO index and agricultural raw material price return

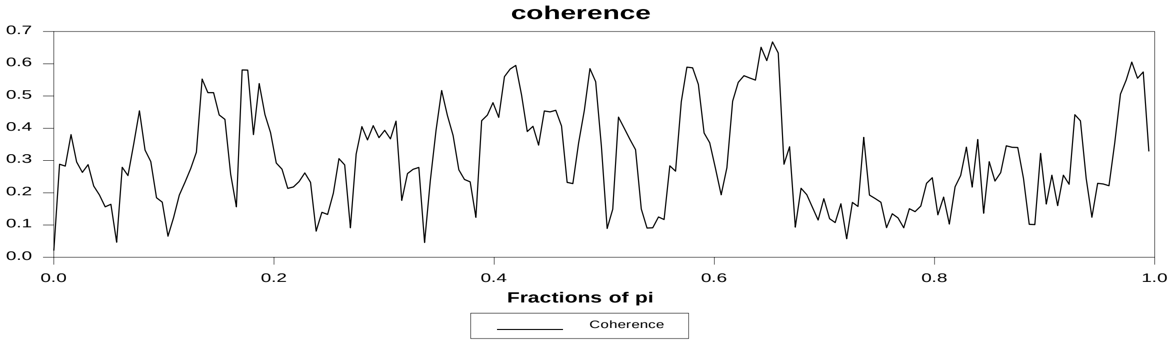
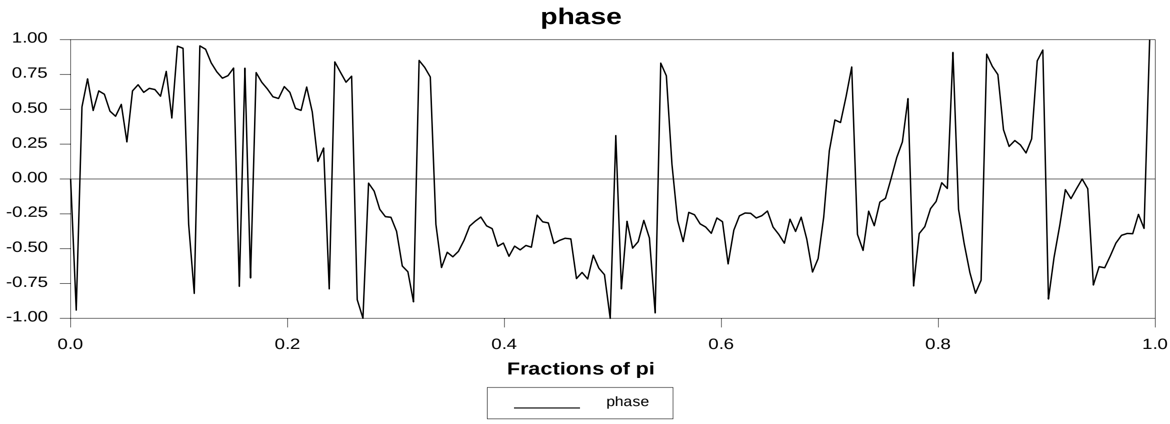
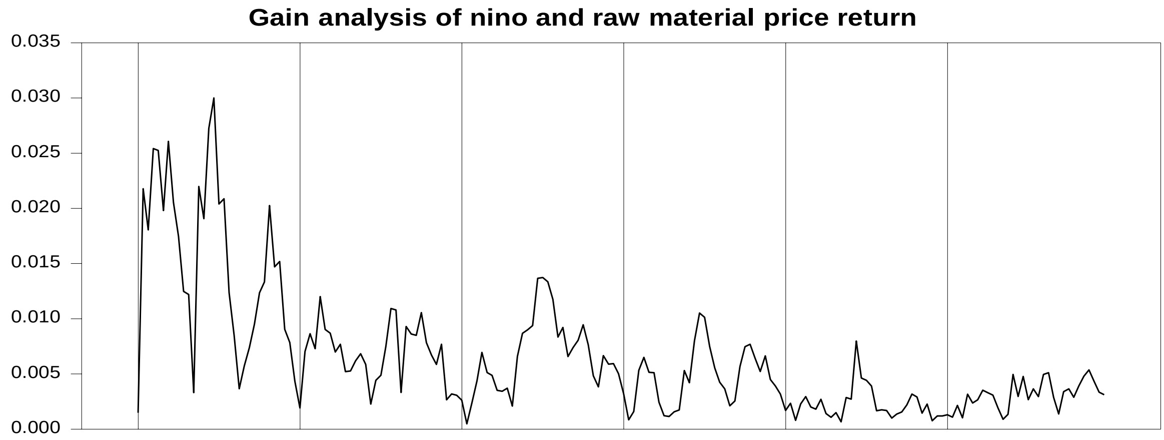


Figure 41c: Phase ENSO index and agricultural raw material price return



Within a long-term relationship of 2 year, a shock on ENSO index affect negatively (the value of the cospectrum is negative) the return of agricultural raw materials price after 2 to 3 months. The figure 41d, tells us that, the amplitude of this impact is 0.03% after 2-3 months.

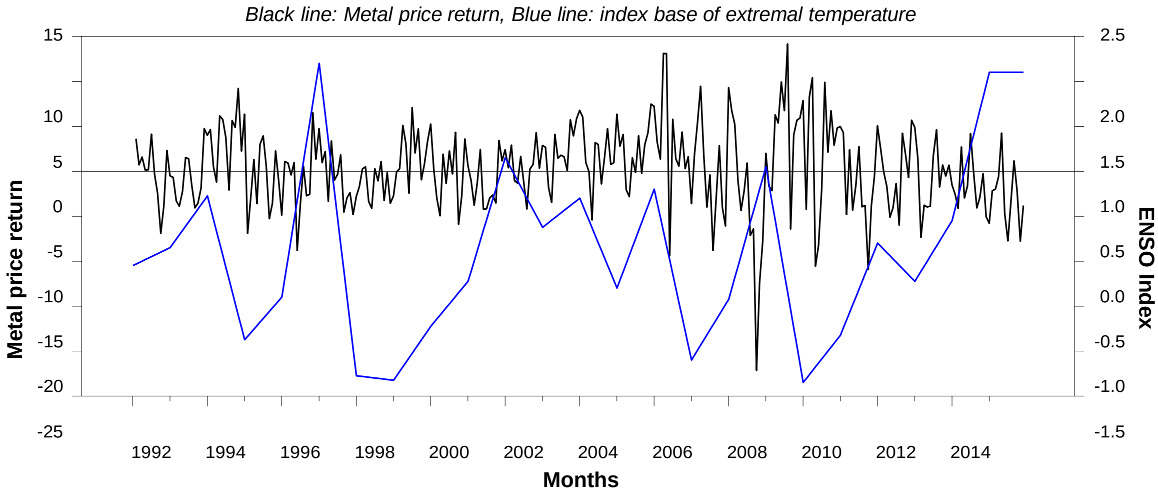
Figure 41d: Gain ENSO index and agricultural raw material price return



6. ENSO shocks impact on the return of metal price

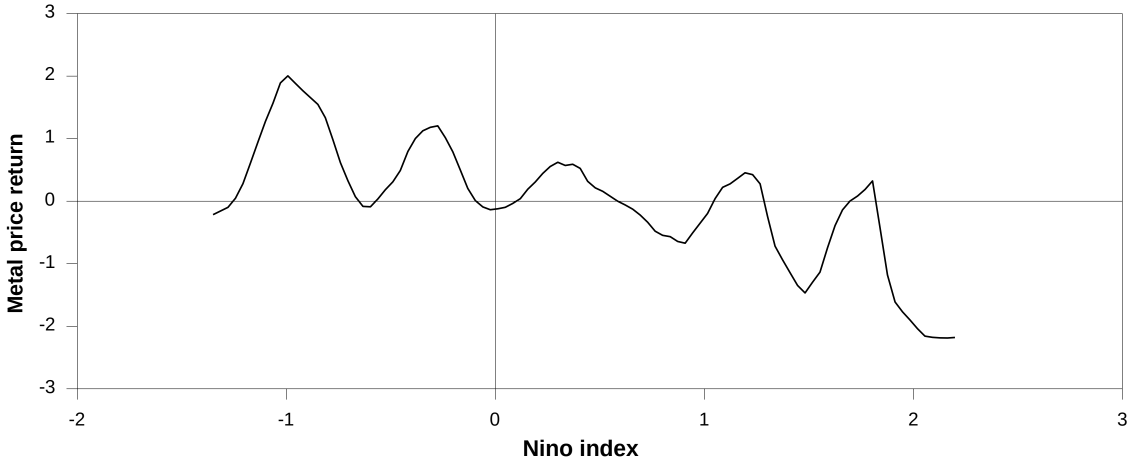
Like in the previous cases, from the figure below, it's hard to see if the ENSO index and the return of metal price are correlated. This figure shows that the lowest values of this return may be associated to El Nino episodes. Also it's hard to better describe the type of relationship which may exist between the two time series. By using a non-parametric regression and a co-spectral analysis, we can overcome this problem.

Figure 42: Metal price return and extremal temperature conditions



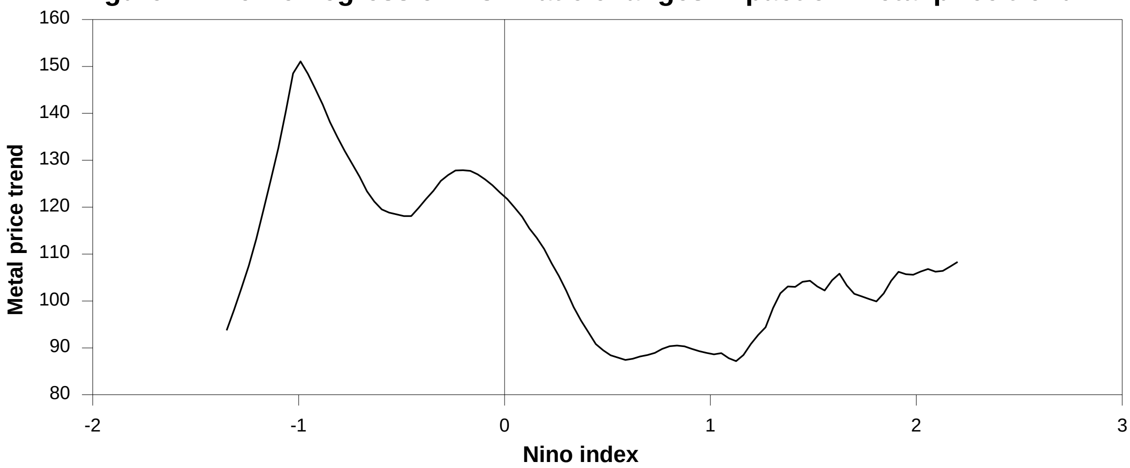
The kernel regression between the ENSO index and the return of metal price (figure 43) shows that the two series are correlated. We can see that, negative returns of metal price are associated to El Nino episodes, while La Nina episodes are mostly associated to positive values of this return. However, the effect of ENSO index on the return of metal price is more nuanced. A weak El Nino is negatively correlated to this return. And a moderate El Nino episode has a negative impact on it, while a strong El Nino episode tend to have a positive impact on it. The position of investors after an El Nino episode should therefore depend on its intensity.

Figure 43: Kernel regression : Climatic changes impact on metal price return



From figure 44 we can see that the impact of ENSO on the trend of metal price is not significant for El Nino episodes, while it is significant and negative for La Nina episodes. On average, La Nina episodes are associated to a falling trend.

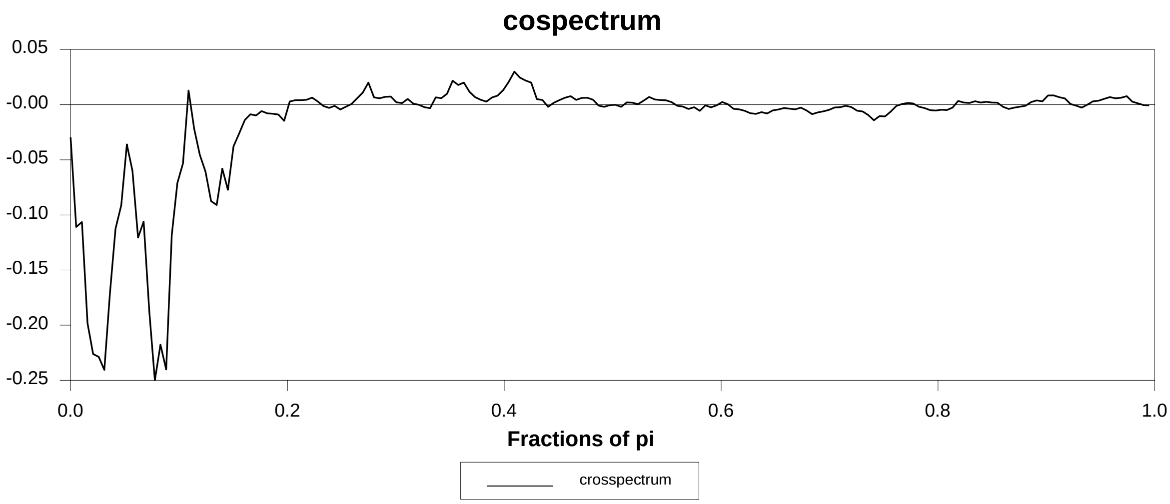
Figure 44: Kernel regression : Climatic changes impact on metal price trend



The figure 45a, shows that the cospectrum is negative at low frequencies, while at high frequencies its values is near 0 and is mostly positive. This suggests that the ENSO index and the return of metal price have a long-term relationship and may be negatively correlated.

The intensity of the correlation between these two series lies between 0.1 and 0.7 (see figure 45b). At low frequencies the value of the coherence can reach 0.6, suggesting a strong correlation between the two time series at these frequencies.

Figure 45a: Cospectrum ENSO index and metal price return



The phase fluctuate between positive and negative values (figure 41c) at low frequencies. The ENSO shocks has an effect on the return of agricultural raw material price, when the value of the phase is positive.

The significant pic of the cospectrum is observed at the frequency of 0.242. At this frequency, the value of the coherence is equal to 0.61, and the value of the phase is 0.90.

Therefore, we can say that, the long-term relationship between ENSO index and the return of the metal price has a duration of 2.16 years. Also this return lead the ENSO index by 3 to 4 months. The impact of ENSO shocks on the return of metal price is not immediate, and is moderate.

Figure 45b: Coherence ENSO index and metal price return

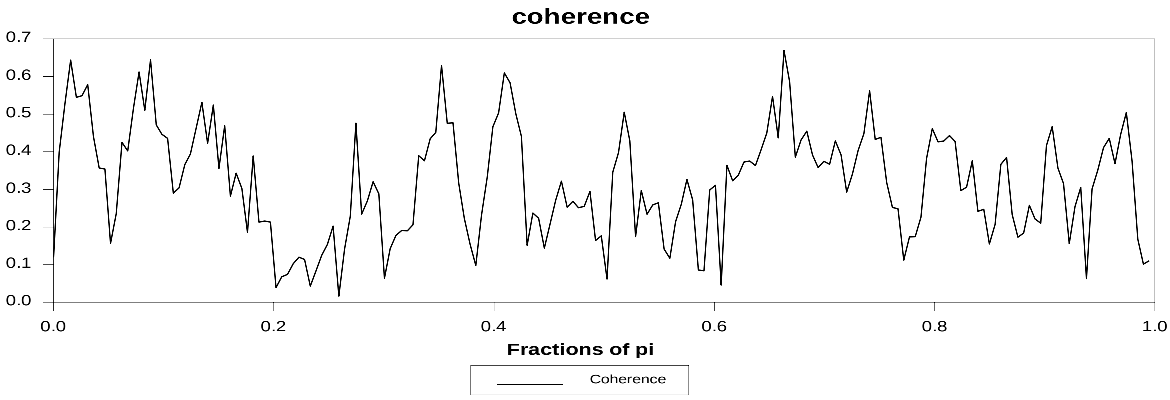
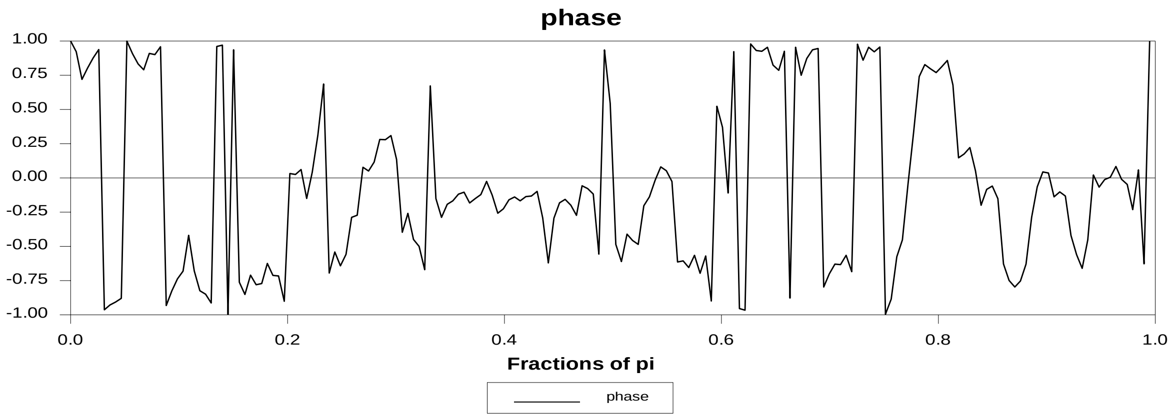
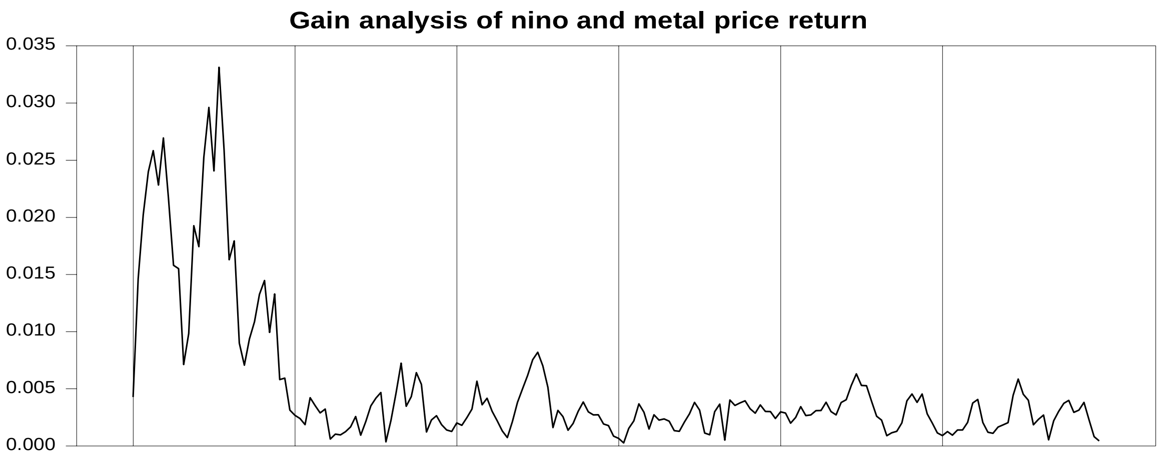


Figure 45c: Phase ENSO index and metal price return



Within a long-term relationship of 2 year, a shock on ENSO index affect negatively (the value of the cospectrum is negative) the return of metal price after 3 to 4 months. The figure 45d, tells us that, the amplitude of this impact is 0.029% after 3-4 months.

Figure 45c: Gain ENSO index and metal price return



CONCLUSION

In summary, we can say that ENSO index has a significant, and long-term effect, on the returnprices of the six commodities studied. This effect, although moderate overall, varies from one commodity to another. It is negative for non-fuel, fuel, metals, and agricultural raw materials, and positive for rice and wheat.

For rice and wheat, the co-spectral analysis shows that a shock on the ENSO index affects the return price of these commodities very quickly (within 1 month) and that, the effect of these shocks can last between 2 and 3 years.

For fuel, and non-fuel, this impact occurs less quickly (2 and 3 months), and also lasts less long(1 to 2 years). For raw materials and metal, the impact of the ENSO shock lasts as long as forrice and wheat, but is slower (2-4 months before its manifestation).

The non-parametric regression allowed us to distinguish the effects of El Nino and Nina from this overall effect of ENSO. For all six commodities, this regression revealed that El Nino is generally correlated with negative values for the return of prices, and La Nina is correlated withits positive values. However, the analysis revealed that the nature and intensity of this correlation also depends on the intensity of El Nino and La Nina.