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RELAÇÃO ENTRE O US DÓLAR, PREÇO DO PETRÓLEO E ALGUMAS MERCADORIAS
THE NEXUS BETWEEN US DOLLAR, OIL PRICE AND COMMODITY INDEX

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Economia, realizada sob a orientação científica do Doutora Mara Madaleno, Professora Auxiliar do Departamento de Economia, Gestão, Engenharia Industrial e Turismo da Universidade de Aveiro.

Dedico este trabalho à minha família, pelo seu total apoio e pelo seu incansável papel na minha vida.

o júri

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palavras-chave Índice US Dólar, Mercadorias, Overshooting, Relação entre US Dólar e o petróleo

resumo

Esta pesquisa investiga a relação entre o índice US Dólar e algumas mercadorias, tais como petróleo, ouro, prata, agricultura, gorduras e óleos, metais e minerais. De acordo com os autores Radomski (2016), Hawkes (2015) e Hameed e Arshad (2008), a relação Dólar Americano / petróleo pode ser assumido como um fator que influencia o valor de outras mercadorias. Assim, com os resultados fornecidos pelo quadro teórico e a análise empírica, esta pesquisa tem como objetivo responder às seguintes questões: a relação entre os preços do petróleo, as taxas de câmbio e os preços das mercadorias, difere por causa do tipo de mercadorias? Por que o efeito do petróleo e do dólar deve variar devido ao tipo de mercadoria?

Para estudar as relações entre o índice US Dólar e o valor de algumas mercadorias, foram utilizados três períodos diferentes, o primeiro de janeiro de 1990 a dezembro de 1999, o segundo de janeiro de 2000 a dezembro de 2007 e o último de janeiro de 2008 até dezembro de 2015. Neste estudo, a estacionaridade é testada, o teste de Johansen é usado para estudar a cointegração, os critérios de informação de Akaike (AIC) para observar quantos atrasos devem ser usados em estimativas, o modelo Vetorial de Correção de Erros (VECM) para observar se há relações unidirecionais ou bidirecionais e estimação da decomposição da variância de erros de previsão (FEDV) para observar como uma mudança nos retornos pode explicar a variância dos erros das demais variáveis em análise.

As principais conclusões observadas após os resultados empíricos e suporte teórico foram que a relação entre as variáveis varia de acordo com o período estudado.

Os resultados empíricos não mostraram uma relação entre o índice US Dólar com o crude como diretriz dos valores das outras mercadorias. Os resultados da FEDV apoiaram alguns sinais de overshooting dos valores das mercadorias em uma diminuição do valor do índice US Dólar. Estes resultados são úteis para que os investidores entendam melhor como eles poderão gerir as suas carteiras de investimento de modo atenuar futuras perdas.

keywords

US Dollar Index, Commodity, Overshooting, US Dollar/Crude oil relationship
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abstract

This research investigates the relationship between the US Dollar Index and some commodities such as Crude Oil, Gold, Silver, Agriculture, Fats and Oils, Metals and Minerals. According to authors Radomski (2016), Hawkes (2015) and Hameed and Arshad (2008) the US Dollar/ Crude Oil can be assumed as a driver of the value of other commodities. So with the results provided by the theoretical framework and the empirical analysis, this research has the purpose to answer the following questions: Does the nexus between oil prices, exchange rate and commodity prices, differs because of the type of the commodity? Why the effect of oil and dollar should differ due to the different commodity type?

To study the relationships between the US Dollar Index and the value of some commodities, there were used three different periods, the first one form January of 1990 to December 1999, the second one from January 2000 to December 2007 and the last one from January 2008 to December 2015.

In this study the stationarity is tested, used the Johansen test to study the cointegration, the Akaike information criteria (AIC) to observe how many lags should be used into estimations, the vector error correction model (VECM) to observe if there is unidirectional or bidirectional relationships and estimated the forecast error variance decomposition (FEDV) to observe how a change in returns can explain the variance of the errors of the other variables under analysis.

The main conclusions observed after the empirical results and the theoretical framework were that the relationship among variables differs according to the period that was studied. The empirical results did not show a strict relationship between the US Dollar/Crude oil as a driver of the values of the other commodities. The results of the FEDV supported some signs of overshooting from the values of the commodities on a decrease of the value of the US Dollar Index. These results are useful for investors to understand how they could manage their investment portfolios in order to ensure minimum losses depending over the investment period.

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List of Acronyms

ADF - Augmented Dickey Fuller

AIC - Akaike Information Criterion

AR - Autoregressive Model

Bbl – Barrel (unit) Mbpd - thousand barrels of oil per day

BIC - Bayesian Information Criterion

CE - Cointegrated Equation

CPI - Consumer Price Index

DOLS - Dynamic Ordinary Least Squares

ECB - European Central Bank

ERS - Elliot-Rottenberg-Stock

FDI - Foreign Direct Investment

FED - Federal Reserve System

FEVD - Forecast Error Variance Decomposition

FMOLS - Fully Modified Ordinary Least Squares

FPE - Finite Prediction Error

GATT - General Agreement On Tariffs And Trade

GDP - Gross Domestic Product

HQC - Hannan and Quin Criterion

ICT - Information and Communication Technology

IMF - International Monetary Fund

MF-DCCA - Multifractal Detrending Moving Average Cross-Correlation Analysis

OECD - Organisation for Economic Co-operation and Development

OPEC - Organization of the Petroleum Exporting Countries

PEPI - Peg the Export Price Index

PPI - Producer Price Index

PRA - Price Reporting Agencies

PUR – Panel Unit Root

SBC - Schwarz Baysean Criterion

SVAR - Structural Vector Autoregression OLS - Ordinary Least Squares

US – Unites States

VAR - Vector Autoregression

VECM - Vector Error Correction Model

WTI - World Trade Index

WTO - World Trade Organization

1. Introduction

The price of the commodities has been a relevant subject of study all over the world. The importance of this topic in the world's economy is notorious, because their prices matter for the country's external and internal balances as well their respective fiscal and monetary policies. Frankel (2008) notes how the low levels of commodity prices in the late 1980s and 1990s may have played a role in some of the financial crises in commodity exporter emerging markets, deteriorating their current accounts.

We can observe this problem in the current period. Smith et al. (2014) states that all of the OPEC member states (except Qatar) can no longer rely on oil exports to balance their budgets. Khan (2017) shows, that Venezuela, Iraq and Kuwait suffered the largest GDP decreases, and Qatar, Iran and Ecuador the least. On the other hand, Frankel (2008) notes that the decrease in commodity prices had a positive impact in industrial countries like the US, where there has been a decrease of the input prices and consequently of inflation, and this allowed high growth and an increase in employment. So with these two examples, it can be observed the importance of commodity prices to the real economy of a country.

Like most of the countries are not self-sufficient, there are always some goods or commodities the country needs to import, because they are not able to produce them inside borders, or can import it at lower costs than they would have if they produced them. Looking at the international financial transactions in the same period, the increase was even greater than the increase of international commerce, with the average growth of 12% per year in this period. In these twenty years, the international financial transactions grew around 865% Low, Olarrega and Suarez (1998).

McDonald (2012) shows that the importance of the international commerce in the economies is becoming more relevant. The self-sufficiency of the countries is therefore decreasing and the interdependence between countries grew considerably. The international financial transactions are a lot larger than the commercial transactions, and as the commodities' markets work side by side with financial markets, to understand the nature of this relationship we need to keep in mind that the financial markets determine the exchange rates and the interest rates. These two variables are extremely important to world commerce and they are usually ignored by analysts, as the majority of commodities are traded in US dollars. When there is an appreciation for the value of the US Dollar, the countries with exchange rates anchored to this currency lose the power to import commodities. This would make the demand for commodities decrease, leading to a negative shock in their prices Krichene (2008).

Having this context as starting point, this dissertation aims to test the presence of cointegrating relations between the values of the US Dollar Index, and the values of the commodities such as Crude Oil, Gold, Silver, Agriculture, Fats and Oils, Metals and Minerals. The inclusion of these commodities in this research have at starting point the objective to study how the relationship between different type of commodities can be affected by the other different type of "commodities".

With the results provided by the empirical results, this study also has the purpose to answer to two questions: "Does the nexus between oil prices, exchange rate and commodity prices, differs because of the type of the commodity?" and "Why the effect of oil and dollar should differ because of the different commodity type?" Even these two questions are less abstract aims of this study, the econometrical tests weren't just applied to

these ones. The tests were more abroad, not just focusing solely in the answer to these questions. The main reason was because these questions were based in some statements provided by some authors like Radomski (2016), Hawkes (2015) and Hameed and Arshad (2008), where it is assumed that the relationship between US Dollar/Crude Oil as driver of the value of other commodities sometimes is observed but is not always observed. So, the focus of econometrical tests just in one unidirectional relationship like a simple OLS regression could be present, but it was found more interesting to study this relationships in a vector regression like the VEC model to study if it is possible to find a unidirectional relationship or a bidirectional relationship between the variables. Moreover, most of the previous studies analysed in the literature review also used vector autoregressive analysis because interactions among variables in a macroeconomic model are often far more complex than what is captured by a posited long-run equilibrium relations alone. As such, studying the short-run transition dynamics provides a richer understanding of the structure of the model and is thus more useful for a setting aiming to study the relationship between oil prices, exchange rates and commodity price interactions. In the presence of cointegration relationships, as is the case of the present study, we should apply the VEC model. One of the reasons that the error-correction model is considered to be a powerful tool is because it provides an excellent framework within which it is possible to apply both the data information and the information obtainable from economic theory, which provides the basis to formulate a long-run level relationship, and an error correction model can be used to empirically test the validity of the relationship.

To answer the above stated questions and provided the presence of cointegration relationships between the variables, the ADF test is going to be run first to test the stationarity. Afterwards, were applied criterions for lag model selection like the Akaike information criterion (AIC), the Schwarz-Bayesian information criterion (SBC) and the Hannan–Quinn information criterion (HQC). Also, the Johansen test was applied for the existence of cointegration and see if in this study it should be used a VAR model or a VECM model. Finally, the VEC model was applied to study the interactive relationships between the variables, and within this model approach we have computed the FEDV to see how the return shocks of the variables affect the variance of the others.

The main reason to study this topic is related to a big interaction between the financial fields and the macroeconomic ones. In this research no macroeconomic variables were used explicitly in the econometric tests, but the importance in macroeconomic terms, for example between metals and crude oil, is high. The Chinese and American economies are the main consumers of these two goods, and so the demand for these is considerably important to establish and understand their values and joint movements. So even if there are not many macroeconomic variables on the econometrical tests present in this study, some values of some commodities can be explained by macroeconomic factors movements, like those of exchange rates. Again, in the perspective to justify the relationship between the financial fields and the macroeconomic one, the Subprime Crisis different period analysis can be a good supporter of this one, because the crisis had a starting point in the financial markets that spread all over the economy, provoking a recession on the World GDP around 3%, according to the data found on the newspaper World Bank (2017).

The structure of this research is going to have three main parts. The first introduces the theoretical framework with some of the explanations of theories related with the topic, some definitions, and some theoretical framework describing the results of some authors with similar studies. The second part is going to present the

description of the data used on this research, and the description of the econometrical tests that are going to be run. Finally, the third part and last one, presents the results of the econometrical tests used in the research, providing some explanations for the achieved results, and offers a discussion part where it is supposed to present the answers to the two main questions proposed by this research. This work finishes with the presentation of a main conclusions section where the most important results achieved are stated.

2. Theoretical Problem Analysis

2.1. Definition of Commodity

According to Copeland and Weston (1988) and Geman (2005) the term ‘commodity’ can be defined as a physical asset that has standardized characteristics, which can be widely negotiated in several localities, and can be transported and stored for a long period of time. ‘Commodity’ can still be defined as a type of product with which there are no qualitative differences between the markets where it is traded. So, between deals of the same product in different markets, there is no preference in terms of quality by the buyers of the product. Copeland and Weston (1988) claim that there may be small differences in quality between each batch traded, but these differences must be within acceptable limits and previously specified in supply contracts.

According to Geman (2005), the term ‘commodity’ can be attributed to a consumer product, the scarcity of which in the form of exhaustion in the extraction or in the reduction of global stocks, which will have an impact on the worldwide price. The author defines the same value in relative terms, in different currencies, and that it can be used with reference to value.

It is common that commodity terminology is attributed to inputs or raw materials. This is because the inputs have not yet been industrially transformed, which facilitates standardization. When a product undergoes transformation in the industry, it gains particular characteristics that distinguish it, making standardization and negotiation on a large scale harder.

Copeland and Weston (1988) suggest that a commodity is an asset where standardization allows the execution of more negotiations, which favours liquidity. In organized markets such as stock exchanges, it is important that the traded asset arrangements allow the presence of liquidity, which in this case can be understood as the facility to buy or sell the position quickly and easily. If a particular broker is in a buying position for a particular asset, he will be able to move out of the position quickly by selling his asset in a liquid market. A necessary condition for liquidity provisions in organized markets is standardization, which allows for agility in the negotiations, starting from the premise that the counterparties involved in the operation know the characteristics of the merchandise traded in advance. The commodity to allow liquidity in the negotiations in an organized market must simultaneously have a series of attributes, according to Kaldor (1939), described as follows:

- The asset must be fully standardized in its characteristics
- Must be a generalized demand asset
- Must be non-perishable goods, that is, the asset should not lose value with the mere passage of time
- The value of the asset must be proportionate to the volume

Kaldor (1939) points out that there are only two classes of assets that satisfy the necessary conditions for large-scale trading. The first class are commodities traded in organized markets. The second class of assets are financial, as securities and shares that have, to the maximum degree, all the attributes described above. Moreover, commodities can be traded in different market types: physical markets which involve the immediate physical delivery of the commodity, or be traded in a virtual marketplace.

2.2. Commodities and Macroeconomics

In the last seventy years, the world economy has experienced a lot of changes. The first one was the emergence of a strong International Financial Market that was based on the Bretton Woods exchange rate. The second was the fall of this system based on Bretton Woods. These two events significantly affected the commodity market. The International Financial Market started to experience exponential growth after the Second World War. This exponential growth can be justified in the first case by the Marshall Plan.

Following De Long and Eichengreen (1991), the Marshall Plan funds were hard currency in a dollar-scarce world. They might have allowed Europe to obtain imports that would relieve bottlenecks. After the war, coal, cotton, petroleum, and other materials were in short supply. The Marshall Plan allowed them to be purchased at a higher rate than would have been possible otherwise. Marshall Plan dollars added to Europe's international liquidity and played a role in restoring intra-European trade. This plan significantly increased the economic relations between the countries that benefited from this plan. Another important factor to increase this economic relation was the high deficits that the US were facing with, for example, related to the huge expenses of the Vietnam War, that led to a huge amount of deposits in European banks.

With the sharp rise of oil prices in the 1970s, the world saw a large increase in the share of the dollars going to the banks were oil producers were depositing them. A large inflow of dollars from the more industrialized countries to the oil producers was observed, resulting in the abandonment of the Bretton Woods FX agreement. This change led to a shift to a more flexible regime of change that drastically altered the monetary and fiscal policies that were the basis of economies.

Before these changes in exchange and financial integration, the changes in monetary policy accentuated the interest rate that was later spread by the economy. With the emergence of capital markets and the adoption of flexible exchange rates, the effects of monetary policies changed. Mejia (1991) argues that constraining monetary policies leads to an influx of capital into the country, which results in an appreciation of its currency, but as such reduces its external competitiveness, favouring imports and harming exports. On the contrary, expansionary monetary policies have the opposite effect. Frankel (2006) mentions, that it is the tradable goods sector that carries the burden of adjustment. The commodities are tradable goods, so they moved from a situation where they were almost untouchable from the monetary policy effects to a situation in which they are really affected from the volatility of exchange rates. For Bergsten (1999), currency and interest rate fluctuations have proved to be a reason for a succession of macroeconomic instabilities and financial crises. For this reason, many emerging countries preferred to keep their currencies tied to the fluctuations of the strongest currencies. Both policies have their positive and negative effects on the economy. Those responsible for these policies must reflect well on what policy to follow for the benefit of their own economy, because each country has its economic dependence on the production of goods or the extraction of commodities, so that exchange policies must meet the economic development of that specific country. Friedman (1968) emphasized the supply of money as the key factor affecting the well-being of the economy, and accepted the need for an effective monetary policy to stabilize an economy.

For Borensztein and Reinhardt (1994) aggregate commodity indices, excluding oil, have been treated as macroeconomic variables whose movements are related to prevailing macroeconomic conditions. Some studies about the determination of commodity prices detected two variables that can explain their

variations. The first one is the economic activity in industrial countries and the other one is the exchange rate of the United States of America. On the other hand, Maia (2003) works on the hypothesis that the exchange rate and the interest rate are particularly important for the performance of the agricultural sector and, consequently, for the performance of its exports. Therefore, the performance and competitiveness of exports should be analysed not only from the exchange rate perspective, but also from the effects that the interest rate produces on the foreign exchange market.

To clarify the effects of these important changes on commodity markets, Barros (1989) focused on three steps. First, he used an exchange rate model to identify and measure the effects of monetary policies on the US exchange rate and its major partners. Second, a model for determining international commodity prices was estimated, showing the effects of changes in the money supply, interest rates, incomes, and the exchange rate on the price of agricultural commodities and on the competitiveness of the US and Brazil. Finally, a two-sector model for the Brazilian economy was used to identify and measure the interactions between international and domestic macroeconomic factors and how they affect national terms of trade through the effects on agricultural and industrial prices.

2.3. The assumption of Sticky prices and formation of Overshooting

Sticky Prices in the short run is an assumption widely accepted by Keynesian economists and generally confirmed by observations and empirical procedures. Okun (1975) states, that commodity prices are more flexible than the prices of other goods and services. Bordo (1980) proved this empirically, showing that commodity prices actually respond more quickly to changes in monetary policy than price of manufactured goods. Subsequently, sticky prices can be assumed in the short run.

Dornbusch (1976) clearly showed that when the prices of foreign currencies were perfectly flexible, they had the freedom to adjust instantly in response to changes in supply and demand, concluding that most other commodities and services had fixed prices in the short run. But sticky prices do not necessarily reflect market imperfections, provided that this stickiness can be explained by adjustment costs.

Frankel (1986) argues that a decline in the nominal money supply is a decline in the real money supply in the short run. It raises the real interest rate, which depresses real commodity prices. They overshoot their new equilibrium in order to generate an expectation of future appreciation sufficient to offset the higher interest rate. These real effects (which vanish in the long run) also result from a decline in the money growth rate.

For Lin and Robers (2006) in general, commodities can be divided into two groups: those that can be stored and those that should not be stored. For example, gold can be stored for a long time at a low cost, in turn electricity has high storage costs which makes its storage impractical. Therefore, commodities as assets that have storage costs must attend to a price loss greater than the fall in the money supply, they should suffer overshooting, because it is the only way to create a rational expectation of future capital gains to compensate the increase in the interest rates. Conversely, an unexpected increase in the money supply will cause a more than proportional increase in commodity prices. The reason for this is justified by the fact that it is the only way to form a rational expectation of future depreciation capable of counteracting the fall in the interest rate.

Brownie and Cronin (2007) explore the relationship between changes in commodity and consumer price levels. According to these authors, both prices respond to a change in the US money supply in the long run. However, commodity prices have a greater variation in the short term (overshooting), and this distancing from the long-run equilibrium will serve as a basis for predicting the future behaviour of the general price level. According to Brownie and Cronin (2007, pp. 9-10), three theoretical propositions are necessary for the elaboration of the commodity price surplus model:

1. Exogenous changes in money supply lead to equivalent changes in the general level of prices under stable conditions of monetary demand;
2. Exogenous changes in the monetary stock are neutral in the long-term steady state, implying the proportional adjustment of all prices, whether final goods or commodities, thus, relative prices remain stable in the new steady state;
3. The third proposition arises from the fact that the commodity market responds more quickly to economic turmoil, including unanticipated changes in monetary policy, forming a flexible price market. In this sense, the response of commodity prices should compensate, in the short term, for the rigidity of prices of consumer goods, surpassing its equilibrium value in the long term.

From these propositions, Brownie and Cronin (2007) suggest testing three hypotheses: (H1) both commodity prices and consumer goods vary proportionately to the variation in the money supply; (H2) commodity prices initially overshoot their long-term equilibrium value; (H3), the correction term for the overshoot of the commodity equilibrium price is an important variable in explaining the gradual adjustment of the prices of consumer goods. Based on these hypotheses, they concluded that if these are confirmed, the commodity price level becomes an important variable for the models of forecasting and analysis used by policymakers, since to a certain extent the behaviour of these prices precedes that of the level of prices and allows adjustments to be made in order to reduce the variation in the general price level.

2.4. The Effect of Monetary Policy on Real Commodity Prices

Monetary policies are currently intended to achieve expected inflation, in other words to achieve the CPI (Consumer Price Index). The monetary policies of the ECB (European Central Bank) are intended to achieve this expected inflation target. Generally, the core inflation rate excludes volatile food products and energy prices. The FED (Federal Reserve System) leader said oil price shocks are to be ignored, and in turn accommodated. But just because the agricultural and mineral products are volatile does not mean that these are not important for the determination of the expected inflation. Prices of gold and other minerals are used to assess expected inflation indicators because they move faster than prices of manufactured goods and services. The Overshooting model according to Frankel (2006) can be summarized as follows. A monetary contraction temporarily raises the real interest rate, whether via a rise in the nominal interest rate, a fall in expected inflation, or both. Real commodity prices fall until commodities are widely considered “undervalued”, so undervalued that there is an expectation of future appreciation (together with other advantages of holding inventories, namely the “convenience yield”) that is sufficient to offset the higher interest rate (and other costs of carrying inventories: storage costs plus any risk premium). Only then, when expected returns are in balance, are firms willing to hold the inventories despite the high carrying cost. In the long run, the general price level

adjusts to the change in the money supply. As a result, the real money supply, real interest rate, and real commodity price eventually return to where they were. The theory is the same as Rudiger Dornbusch's (1976) famous theory of exchange rate overshooting, with the price of commodities substituted for the price of foreign exchange and with convenience yield substituted for the foreign interest rate.

Steffen Osterloh, (2010) studied if the impact of politics on economic growth is presented. He used data derived from content analysis of party manifestos as measures of party preferences. In a panel of 23 OECD countries, he detected a positive impact of party support for various market-liberal policies on economic performance. Additionally, weather, especially in agriculture commodities, and other factors that may have an influence on the supply of commodities, can be considered very important for the oscillations of the prices of a commodity. In general, commodity analysts such as those of oil, coffee, or copper pay little attention to macroeconomic indicators to determine their prices, they usually turn their attention to microeconomic indicators. Given the author's disagreement with the monetary policies that central banks take, it is considered important to include commodity prices in the variables that central banks must drive independently of their regime. Another reason for disagreement is the possibility in the case of countries where trade fluctuations are important, where export prices play an important role in the price index that enters the rule or target than does the CPI (whether headline CPI or core CPI).

2.5. The Proposal to Peg the Export Price (PEPI)

Frankel (2005) originally proposed this model for the countries that are very specialized in the extraction of a mineral or in the agricultural production, where exports of these commodities have significant impacts on the balance of payments of that country. The purpose of this suggestion was to attach the price of this commodity in terms of internal currency, or to attach the price of that currency in terms of the commodity. For example, African gold-producing countries should peg their currency to gold. Canada and Australia should peg to wheat. Norway should peg to oil. The author goes even further, stating that countries such as South Korea which is a major exporter of semiconductors (which is a commodity chip), being a manufactured product, should peg these semiconductors to their currency, given the great weight that this commodity has on their exports.

This theory may also result in the parity of a basket obtained from the combination of the exported commodity with a world-accepted currency, such as the US dollar or the EURO. For example for the Middle East oil exporting countries this basket could be made with 1/3 of US dollars, 1/3 of Euros and 1/3 of oil. To conclude, the author states that this theory has two advantages over CPI targeting. The first one is related to the fact that, for example, a CPI targeting country has to make a contraction if the price of the imported commodity rises, which is the case, for example, of an oil importer. Another advantage is related to the fact that PEPI accommodates the fluctuations of the exported commodity, the CPI in turn does not allow it.

The second argument of the PEPI proposal is to eliminate the variation of the export price. This stability in the export price will in turn contribute to stabilize the balance of payments. A central bank could accomplish this by monitoring a monthly export price index and publishing it. This process is within the reach of most countries, and does not require great knowledge or great technology to do it. For countries with a lack of international credibility, this mechanism could be an asset because it would be more transparent. The components of the CPI in some countries are sometimes not the most reliable such as the price of houses.

PEPI can still be done in another way. This form is less drastic than the others presented. The proposal would be targeting the PPI (Producer Price Index) or the GDP deflator. This proposal has one adversity, since it is difficult to separate non-tradable and exportable goods into two sectors of the production. So the key to this proposal would be to exclude import prices from the index and include the export prices like the PPI does.

After Frankel (2005) came up with the PEPI theory, many authors commented this one. Some agree with this, others disagree. One of the authors who has shown the most disagreement with this theory is Lars Sevensson. Sevensson (2005) agrees with the relationship that is presented in the PEPI in which there is a negative relationship between the interest rate and the price of commodities. But he completely disagrees with the postulate in the PEPI, where it is said that the Central Bank should stabilize the price of exports instead of inflation targeting as the CPI.

Stabilizing export prices can have dire consequences to the economy. But, for example, in a developed and quite diversified economy such as Norway, the stabilization of export prices could be quite harmful to the economy. If we look at oil prices that have a large percentage of Norwegian exports, and where currently the prices of these are about half the value of what they were two years ago, the stabilization of export prices would cause a deflation of around 50% in the CPI which would not be good for this economy (as argued by the author).

When marginal costs and marginal benefits are relatively independent of the real interest rate, we should expect commodity prices to be negatively correlated with the real interest rate. Although in most of the empirical studies of Frankel and others, a negative relation between the interest rate and the price of commodities is revealed, but this relationship is not always verified.

Another question that Svensson has about the PEPI is related to the observed property when an adverse terms-of-trade effect is observed if it mirrors national currency depreciation. If we look at a small open economy, for example, a deferral of the terms of trade can be witnessed, caused by a fall in the price of exports, generated by a depreciation of the foreign currency. With a stable exchange rate, as PEPI tells us, it would indeed require a depreciation of the national currency.

Another criticism of PEPI is related to the increase of import prices, taking into account that there is no symmetrical increase in export prices, and as the exchange rate is fixed, the export price would be the same in national currency. In this case the PEPI needs a constant exchange rate and not a depreciation of currency. Another factor that the author points to the PEPI is once again related to the loss of terms of trade effect, since the world prices of imports and exports increased, but not in equal amounts, and import prices increased more. As the exchange rate is fixed, the domestic price of exports would increase. So, the PEPI needed an appreciation of the national currency. In this model it is not always necessary to depreciate changes in order for a deterioration of the terms of trade to take place.

To conclude, the author states that Frankel did not make any convincing argument that inflation targeting is harmful to the economy. It is actually adopted by the Central Banks of the developed countries and most of the underdeveloped countries and has had positive results. In fact, the International Monetary Fund (IMF) in the World Economic Outlook of September 2005 notes that inflation targeting has worked well in a number of emerging-market countries. No country that has adopted inflation targeting has abandoned it, and no country has ever expressed any regrets. In particular inflation targeting seems to work well even without a number of

so-called preconditions, such as good institutions, well-developed financial markets, responsible fiscal policies, and so forth.

Campbell (2008, P-341) theoretical work by Kosuke Aoki, Pierpaolo Benigno, and others has emphasized that, from a welfare point of view, monetary policy should stabilize sticky prices rather than flexible prices. This minimizes the distortion caused by the existence of sticky prices and brings the economy closer to flex price equilibrium.

2.6. Relationship Between Us Dollar and Oil

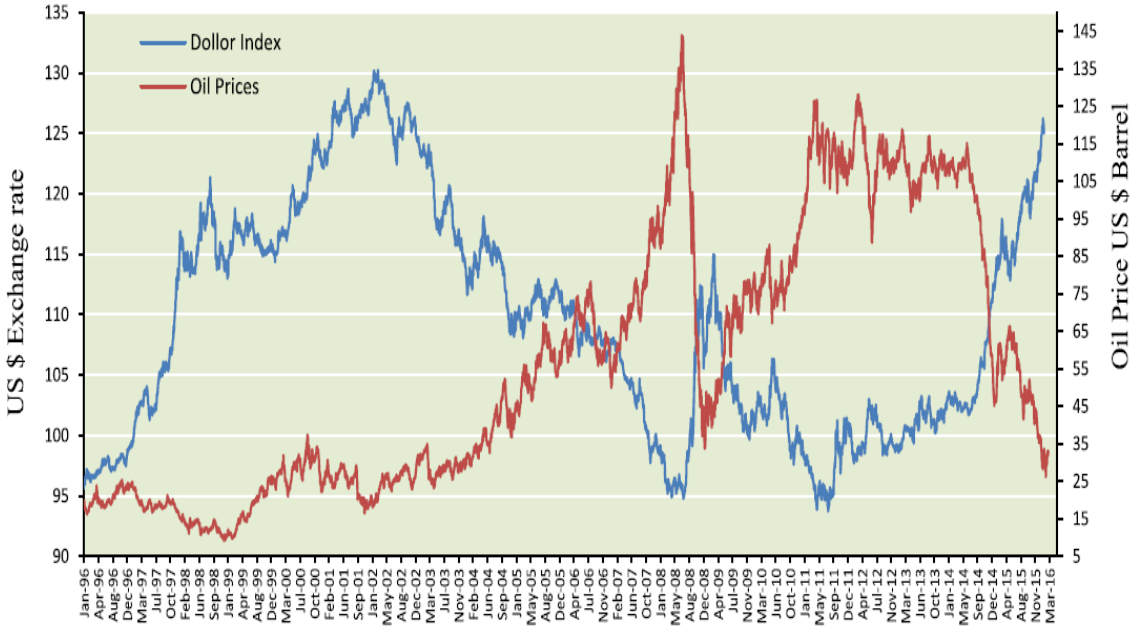
The generality of the authors affirms that this relation has a negative correlation. Where the increase of the interest rate by the FED will lead to the appreciation of the US dollar, which in turn will decrease oil prices or the decrease in the interest rate, will decrease the value of dollar that would increase the oil prices. This occurs because oil, like most of the commodities, is quoted in US dollars, so there is a clear relationship between these two factors, as argued by Munoz and Dickey (2009).

On the demand aspect, the devaluation of the dollar will increase the oil purchase parity for a country that does not have its currency anchored to the dollar Coudert, Mignon and Penot (2005).

On the supply side, the loss of the dollar value of oil may be harmful to the economy, because for a country that has a budget dependent on oil revenues, the fall in oil prices can lead to cash problems Coudert, Mignon and Penot (2005). These countries may have a strong incentive to reduce oil production, so prices will rise again Grisse (2010). Another reason for stopping production may be related to the high costs that extraction may have, where sometimes in certain countries when the price of oil in dollars is low, it is not enough to cover extraction costs.

Figure 1 shows us that if the dollar falls by 10%, it doesn't result in a 10% increase in oil prices. As we can see, the movements in these two factors are not symmetric, it is possible to observe that usually the movements of the U.S. Dollar index are more stable than the movements of the oil prices. Excluding the values observed in 2008, the movement on the U.S. Dollar Index was quite sharp, but that can be explained by the Subprime Crisis that almost ended with the monetary system that we still have today. Crises are crises, they need special measures to decrease their impact on the real economy, and in this period, that was what happened. The FED injected 2.3 trillion US Dollars to keep the stability of the banking system Thornton (2012). So after these arguments, and by looking at figure 1 we can conclude that there is an inverse relationship between the U. S Dollar Index and oil prices.

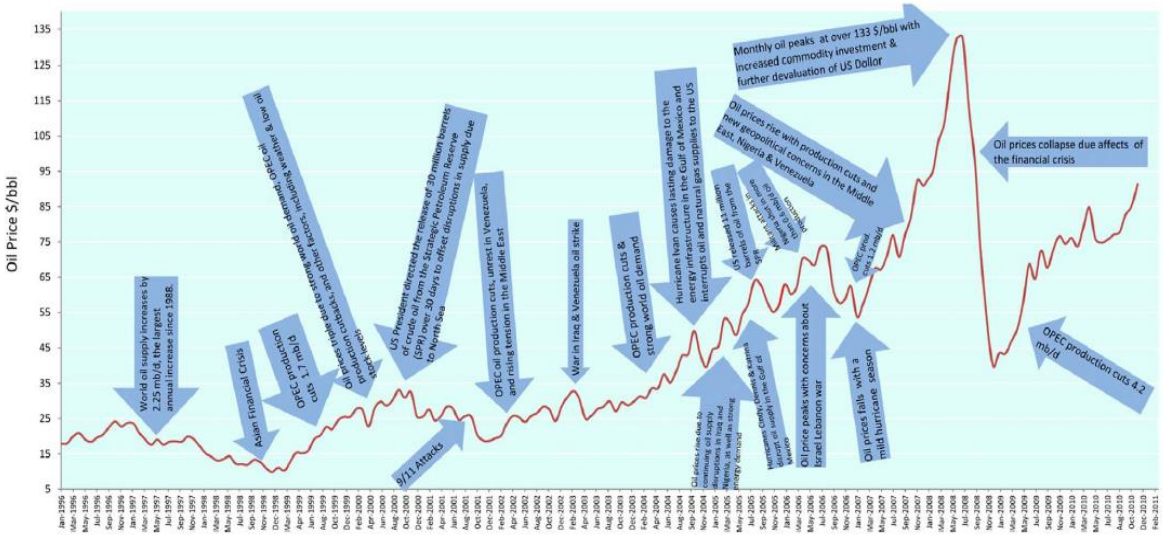
Figure 1 - Oil price versus US dollar index



Source: Khan, (2017), Falling oil prices: Causes, consequences and policy implications, p.12

Ramakrishnan, Butt and Anuar (2017) state that other factors may influence oil prices, such as political motives of producing countries, terrorism, macroeconomic variables. Figure 2 has some of the reasons that led to the behaviour of oil prices from 1996 to 2010.

Figure 2 - Crude oil price trend



Source: Khan, (2017), Falling oil prices: Causes, consequences and policy implications, p.12

Khan (2017) aimed to study the theory of recent oil price declines based on different scenarios to get closer to reality. In this study he tries to answer the following questions:

- How does the recent plunge in oil prices associate with previous episodes?

- What causes a sharp drop in oil prices?
- How do oil prices look in the future?
- How could falling oil prices affect oil exporting and importing countries?
- What are the financial and macroeconomic implications?
- What are the contributions of geopolitical strategies toward recent plunge?

In order to answer these questions, he examined several parameters such as world total liquid production, world total liquid consumption, oil prices; US oil production, US oil imports, oil prices; world oil supply, world oil demand, oil prices; among others, in the period from January 1996 to February 2016. The main conclusions that he got were "It is observed that the supply and demand haven't changed enough to create a 72% plunge in oil prices. It means that the major fall in oil prices since June 2014 may be about a shift in trading (most probably due to the changing role of oil pricing reporting agencies –PRAs), rather than a change in the fundamental supply and demand equation." and "Politics and the tussle between the sole super power and countries that continue to challenge that status quo of the sole supremacy will determine the future of oil crisis that currently exists", Khan (2017, p. 17).

Novotný (2012), in his study goes into the intensity and direction of the relationship between the nominal effective exchange rate of the US dollar and the price of Brent crude oil and other commodities (gold, industrial metals and agricultural commodities). The period analysed was between 1982 and 2010. He demonstrates that growth in industrial production causes an increase in the oil price while interest rates growth causes the oil price to fall. More recently, Kilian and Murphy (2014) developed a structural model of the global market for crude oil. It was the first time that anyone explicitly allowed for shocks to the speculative demand for oil as well as shocks to flow demand and flow supply. They used a VAR model of the global market for crude oil that explicitly nests these two explanations of the determination of the real price of oil and allows us to quantify the effects of different oil demand and supply shocks. They showed that, even after accounting for the role of inventories in smoothing oil consumption, their estimate of the short-run price elasticity of oil demand is much higher than traditional estimates from dynamic models that do not account for the endogeneity of the price of oil.

Ramakrishnan, Butt and Anuar (2017) examined the linkages among the nominal exchange rate, oil prices, terrorism and three selected macroeconomic variables: real growth rate, inflation rate and interest rate. The method used was an autoregressive distributed lag to test the long term and short-term dynamics over the period 1980-2015 in the context of Pakistan. The results showed that the adjustment process is slow and the short-term adjustment indicates that the discrepancies adjust completely in the same period. Hence the efficient monetary and fiscal policy should keep into consideration before devising policies that have a greater influence on the variability of the exchange rate.

Sun, Lu, Yue and Li (2017) investigated the cross-correlations between the US monetary policy, US dollar index and WTI crude oil market. The period was from February 4, 1994 to February 29, 2016. The method used was the MF-DCCA (multifractal detrended cross-correlation analysis) approach to examine the effect of the US monetary policy on US dollar index and WTI crude oil. Their empirical results show that the US

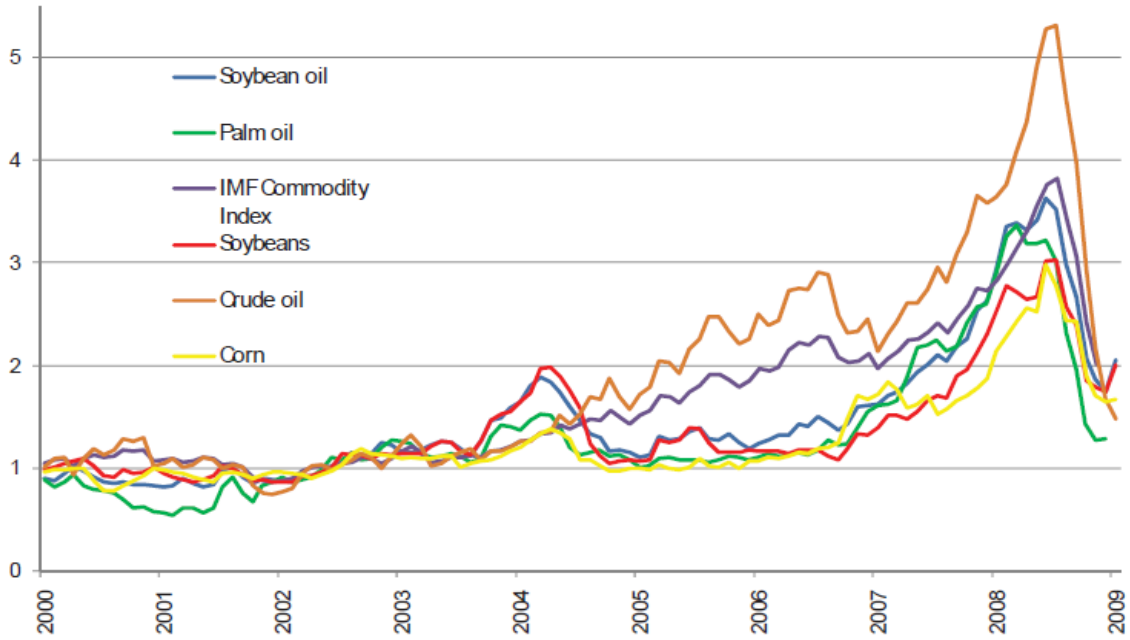
monetary policy operations have clear influences on the cross-correlated behaviour of the three-time series covered by this study.

2.7. Relationship between US Dollar, Crude Oil and Agricultural Commodities

The link between the US dollar and oil here is not different from the one mentioned in the previous chapter of this study. Here, the difference is the inclusion of another variable (Agriculture Commodities). In some related literature, it was proved that there is a relationship between these three factors. Krugman (2008) proved that the increase in oil prices would provide an incentive to produce biofuels, which would be responsible for the increase in food prices.

Figure 3 show that there is some degree of harmonization between the prices of Crude Oil and the others oils. That can be explained by the FED Monetary Policy, but what cannot be denied is the similar trend these different variables have in the same periods. As Abbott, Hurt and Tyner (2009) state, in the July 2008 report, the weak U.S. dollar was recognized as an important factor contributing to high agricultural commodity prices, especially as denominated in dollars. When that report was written, commodity prices were high in any currency and substantially higher in nominal dollars at a time when the dollar had depreciated significantly against many currencies. Dollar depreciation affected crude oil as well as agricultural commodity prices, and raised questions as to the causes of the weak dollar and high commodity prices.

Figure 3 - Energy and Agricultural Commodity Price Indices, 2000-09



Source: International Monetary Fund, International Financial Statistics.

Commodity prices and indices are normalized to equal 1.0, on average, for 2002

http://www.usfunds.com/investor-library/investor-alert/crude-oil-is-the-best-performing-commodity-of-2015-so-far/#.WLxUmTt9602

Gozgor and Kablamaci (2014) examined a systematic interrelationship between the world oil and agricultural commodity prices, taking the role of the USD and the perceived global market risks into consideration. They began by determining the significant cross-sectional dependence in a large balanced panel framework for 27 commodity prices, and then apply the second-generation panel unit root (PUR) tests. The results from the PUR tests clearly suggest that there is a strong unit root in agricultural commodity prices. The period studied was from January 1990 to June 2013. In this study they found that the world oil price and the weak USD have positive impacts on almost all agricultural commodity prices.

Nazlioglu and Soytas (2012) observed in a panel setting the dynamic relationship between world oil prices and twenty-four world agricultural commodity prices accounting for changes in the relative strength of the US dollar. The method they used was a panel cointegration and Granger causality for a group of twenty-four agricultural products based on monthly prices ranging from January 1980 to February 2010. The results of the tests provide a strong evidence of the impact of world oil price changes on agricultural commodity prices. They found evidence for the role of world oil prices on the prices of several agricultural commodities, in the opposite direction of many other studies. One year later, Byrne, Fazio and Fiess (2013) focused on the co-movement and determinants of commodity prices. The primary commodities in this study are agricultural, and have three or four metals like zinc, for example. They used data on commodity prices from 1900 to 2008. Using nonstationary panel methods, they documented a statistically significant degree of co-movement due to a common factor. Within a Factor Augmented VAR approach, real interest rate and uncertainty, as postulated by a simple asset pricing model, are both found to be negatively related to this common factor. This evidence is robust to the inclusion of demand and supply shocks, which both positively impact the co-movement of commodity prices.

Campiche, Bryant, Richardson and Outlaw (2007) examined the covariability between crude oil prices and corn, sorghum, sugar, soybeans, soybean oil, and palm oil prices, during the period of 2003-2007, and used Johansen cointegration tests. The Johansen cointegration tests revealed no cointegrating relationships during the 2003-2005 time frame. However, corn prices and soybean prices were cointegrated with crude oil prices during the period of 2006-2007.

Zanias (2005) studied the trade between primary commodities and manufactured goods, using statistical tests that take into account breaks in the series, data series covering almost the whole of the 20th century. He found that over the 20th century, the relative prices of primary commodities dropped to nearly one-third of their level at the beginning of the century in two "instalments".

Abbott, Hurt and Tyner (2009) identified three major driving forces of food prices: world agricultural commodity consumption growth exceeding production growth, leading to very low commodity inventories; the low value of the U.S. dollar; and the new linkage of energy and agricultural markets. Using statistical tests that take into account breaks in the series, data series cover the last 30 years. They concluded that the future agricultural commodity price changes will depend strongly on exchange rates and crude oil prices, which in turn are linked and depend on macroeconomic performance. In the same year, Cooke and Robles (2009) focused on the international price of corn, wheat, rice, and soybeans from 2006 to mid-2008. First, they identify variables associated with the factors mentioned as causing the increase in these agricultural commodity prices. Secondly, they used time series analysis to try to quantitatively validate those explanations. There is evidence

that financial activity in futures markets and proxies for speculation can help explain the observed change in food prices.

Recently, Guellil, Belmokaddem and Benbouziane (2016) examined the long-term relationship and causality between world oil prices and twenty-two world agricultural commodity prices accounting for changes in the relative strength of US dollar in a panel setting. They used the panel cointegration method and a panel Granger causality estimation based on FMOLS and DOLS estimators of the principal system from the period 1980-2015. This study shows strong evidence of the impact of the oil prices on the agricultural commodity prices. But contrary to many other studies that pointed out the neutral causality of agricultural prices to oil price changes, they got strong support for information transmission from world oil prices to several agricultural commodity prices.

Rezitis (2015) looked at the relationship between crude oil prices, US dollar exchange rates and 30 selected international agricultural prices and five international fertilizer prices in a panel framework. To test it, they used panel VAR methods and Granger causality tests on panel data sets of agricultural commodity prices, from June 1983 to June 2013. Contrary to the findings of several studies in literature, the present study supports bidirectional panel causality effects between crude oil prices and international agricultural prices as well as between US exchange rates and international agricultural prices.

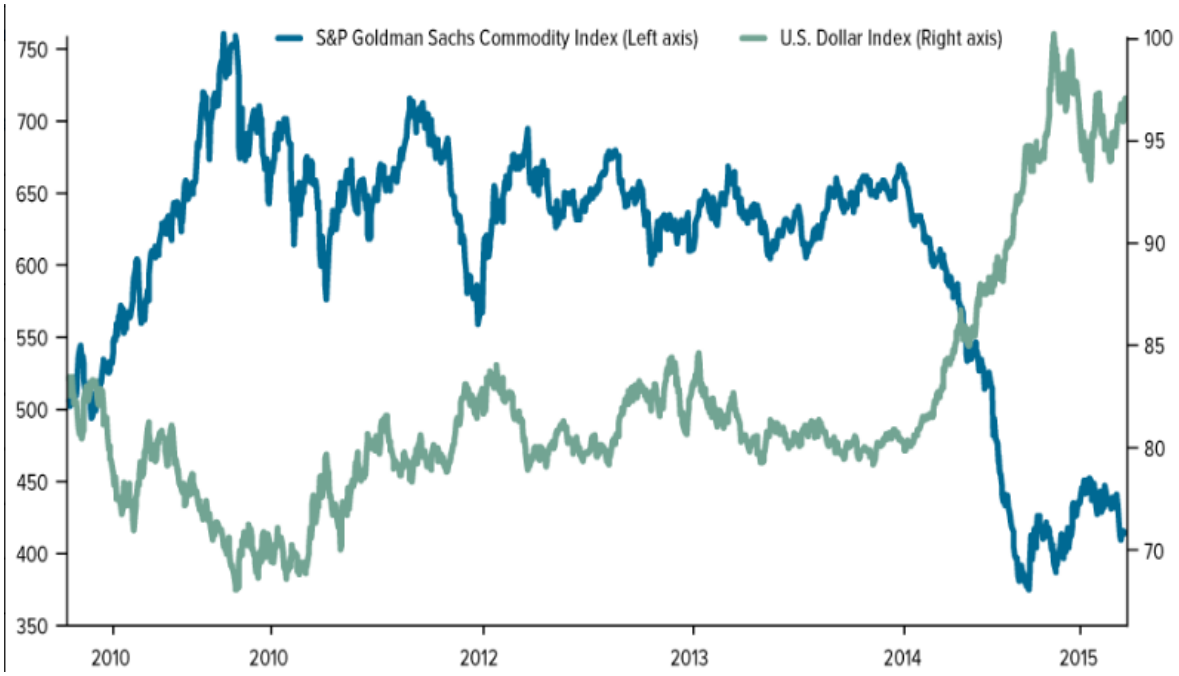
Filip, Janda, Kristoufek and Zilberman (2016) examined co-movements between biofuels and a wide range of commodities and assets in the US, Europe, and Brazil. They analyse a unique dataset of 33 commodities and relevant assets (between 2003 and 2016) which is unprecedented in biofuel literature. They combine the minimum spanning tree correlation filtration to detect the most important connections of the broad analysed system with continuous wavelet analysis, which allows for studying dynamic connections between biofuels and relevant commodities and assets, as well as their frequency characteristics. The main conclusion was that financial factors do not significantly interact with biofuel prices.

Akdogan (2017) tested whether there is mean-reverting behaviour in the unprocessed food prices towards a long-term trend. Data consist of monthly unprocessed food price series of 24 European countries, from January 1996 to July 2016. They first conducted three linear unit root tests that are extensively used in literature: Augmented Dickey Fuller (ADF), Elliot-Rottenberg-Stock (ERS) and Phillips-Perron tests. Secondly, non-linear unit root tests were performed. Thirdly, non-linear models are estimated and an out of sample forecasting exercise of these models is implemented. The main conclusions indicate that for some countries the unprocessed food price series display non-linear behavior, in alternative smooth transition forms including asymmetries depending on the sign and size of the deviation from the long-term mean.

2.8. Relationship between US Dollar and Commodities

Positive or negative economic shocks can have an impact on macroeconomic variables, which may affect the monetary policies. Those policies have a direct impact on the commodity index prices. The impact is not always the same and it is impossible to predict, because each case is unique, but as we observe in figure 4, that inverse relationship is quite evident.

Figure 4 - Inverse Relationship between the US Dollar and Commodities



Source: Bloomberg US global Investors

Belke, Bordon and Hendricks (2010) studied the interactions between money, interest rates, goods and commodity prices at a global level. To study the relationships, they aggregated data from the major OECD countries and followed the Johansen/Juselius cointegrated VAR approach. The period studied was from the 70s till 2008. The empirical conclusion results were according to the previous theories. The inclusion of commodity prices helps to identify a significant monetary transmission process from global liquidity to other macro variables such as goods prices.

In the current year, Seyyedi (2017) investigates the co-movements and linkages among gold prices, oil prices, and Indian rupee–dollar exchange rates to investigate whether Indian economic policy-makers should detach financial policies from energy policies. The period selected was from 12 January 2004 to 30 April 2015. They find that gold prices, oil prices, and rupee–dollar exchange rates stay substantially independent from each other, which denotes that energy policies and financial policies must be detached.

Chen (2015) wanted to investigate the common movements of commodity sectors in China as well as the economic underpinnings of the co-movements. He employed a Bayesian dynamic latent factor model to disentangle the common and idiosyncratic sector-specific factors of the prices of a group of China's commodity sectors: petrochemicals, grains, energy, non-ferrous metals, oils & fats and softs from July 2004 to June 2014. The main conclusion of this study was that the global oil price shocks have strong effects on the common movements across commodity sectors in China in addition to its domestic macroeconomic fluctuations at long horizons.

Gelos and Ustyugova (2017) related the inflationary impact of commodity price shocks across countries to a broad range of structural characteristics and policy frameworks over the period 2001–2010. Their dataset comprises 31 advanced and 60 emerging and developing economies. This analysis suggests that economies

with higher food shares in CPI baskets, fuel intensities, and pre-existing inflation levels were more prone to experience sustained inflationary effects from commodity price shocks.

Hammoudeh, Khuong Nguyen, and Sousa (2014) examined the effect of the monetary policy of China in commodity prices. The period analysed is from January 1990 to April 2013. The Bayesian Structural VAR (SVAR) is the model used to investigate this relationship. The study proves that a positive (contractionary) shock to the interest rate of the Chinese central bank lowers the aggregate commodity price index. More recently, Harvey, Kellard, Madsen and Wohar (2017) studied the historical relation between a new aggregate index of commodity prices, economic activity, and interest rates. They applied a stationary VAR to model movements around trends to assess the relationships between economic series. The results of the study prove and show that there is evidence that commodity prices Granger cause income and interest rates, while interest rates Granger cause commodity prices.

Previously, Akram (2008) investigated if a decline in real interest rates and the US dollar contribute to higher commodity prices, or if commodity prices tend to display overshooting behaviour in response to changes in especially real interest rates. The data used was from 1990Q1–2007Q4 about a broad range of real commodity prices, such as real prices of crude oil, food, metals and industrial raw materials. He used structural VAR models. The empirical results show that commodity prices increase significantly in response to a reduction in real interest rates. The oil prices as well as metal prices tend to display overshooting behaviour in response to interest rate changes.

Also for the US economy, Hammoudeh, Nguyen and Sousa (2016) studied the impacts of the monetary policy of the United States on commodity prices. They use a Bayesian Structural VAR to study this relationship. The study period ran from January 1957 to March 2008. They concluded, with the tests, that in the beginning, a contractionary monetary policy (increased interest rate) would, in the first case, increase the prices of non-fuel commodities, which later reverts the path and becomes negative.

Frankel (2013) focuses on speculative factors, here defined as the trade-off between interest rates on the one hand and market participants' expectations of future price changes on the other. He uses a VAR model to study the relationship between these factors and OLS for the estimation of the equation to determine the price of oil. The period observed is from 1950-2012. He found a negative effect of interest rates on the demand for inventories and thereby on commodity prices and positive effects of expected future price gains on inventory demand and thereby on today's commodity prices.

With all these previously identified relationships found by previous authors it is defined next the research questions which will be tested in the following sections.

2.9. Outlook of the Macroeconomics trends in the 90s

The 1990s began with the collapse of the Soviet Union and the end of the Cold War, followed by the consolidation of democracy, globalization, and global capitalism. This decade was marked by events such as the Gulf War and the popularization of the personal computer and the Internet, and some financial crisis, such as the Mexican crisis in 1994, Asian crisis in 1997 and the Russian crisis in 1998. Another important thing that happened in this decade was the substitution of the GATT (General Agreement on Tariffs and Trade) for the

WTO (World Trade Organization). This change was done to create a new institution more capable to regulate the world trade between countries.

The impact of the Soviet Union and the creation of the WTO isn't easy to observe in the commodity markets, because in the commodity markets, usually the impact of some evens in the period they happened instant observed, and the consequences of this events had more impact in macroeconomics indicators in the long run than in the short run. It is not easy to observe trends in the commodity markets related with these two events, but still they should not be forgotten.

According to Zagha (2005), after the collapse of the URSS, Russian Federation, Eastern Europe, and Central Asia embraced capitalism and a new generation of leaders made it a priority to rebuild their economies based on capitalist principles, markets, and privatized firms. The world observed an increase in the international trade with the main economies becoming more opened like Russia for example, one of the biggest commodity exporter such as crude oil, agricultural and metals. The inclusion of this country in the developed financial markets had impact in the prices of commodities. The creation of WTO was important to regulate and smooth the global trade with the inclusion of ex URSS countries in the financial markets.

Let's focus now on the crisis presented above because this even had impact on the financial markets, as commodity markets and currency markets. The Mexican crisis in 1994 did not had much impact on the commodity market but, it should be mention because one of the reasons of this crisis was related with the drop of the prices of a commodity that was responsible for the deficit in the Mexican balance of payments. This has affected negatively this economy leading to a big decrease of FDI and decreased substantially the value of the Mexican peso.

The Asian crisis according to Hammoudeh and Li (2004), observed the presence of fewer co-integrating relationships in the post-crisis period which can be the result of less discipline among the OPEC countries during a crisis period and a lack of international policy coordination as is the case in the exchange rates during a crisis. The result could also indicate the petroleum markets have become less stable after the crisis. According to Wiel (2013) it was observed a decrease in the demand for nonferrous metals, and an oil price drop because of the Asian crisis. That severely affected Russia's budget deficit and also its current account balance. It was one of the main factors that lead Russia to face a crisis. In the period of the Asian and Russian crisis there was an increase on the value of the US Dollar index, and a decrease in all the commodities studied on this research.

2.10. Summary of the economics growth from 2000-2007

The period 2000 to 2007 was marked by high economic growth. But on the social and political side, not everything was positive. In 2001 the terrorist attack to the World Trade Center in New York (USA) was one of the biggest terrorist attacks that the modern world has ever seen, about 3000 people died, and as a result this attack provoked a friction between some Islamic and Western countries. These frictions led to wars in some countries such as the War in Afghanistan, and in Iraq. In the first of January, 2002, the coins and physical notes of the Euro entered into circulation.

Although there has been a high economic growth, the decade begins with the bursting of the Dot-com bubble. It was a speculative bubble created in the late 1990s, characterized by a sharp rise in stocks of the new Internet-based information and communication technology (ICT) companies. This crisis leads again the values of commodities to go down again after a small recovery in the aftermath of the Asian and Russian crisis in the end of the 90s.

The effect of the Dot-com bubble in the commodities vanish fast. The resumption of public investments in strategic sectors of infrastructure, were responsible for that vanishing. This investment mainly occurred in China, Russia, Argentina, Brazil and in some European countries. This investment increased the industrial production and construction sector, which increased the prices of the crude oil, agriculture and metals. The world economy was experiencing one of the longest periods of prosperity and stability in history by the end of 2007 when the crisis of high-risk mortgage credit is put on the line, putting the economies of several countries, especially developed ones, at risk.

2.11. Summary of the economic growth from 2008-2015

This period starts with The Great Recession, one of the biggest economic crisis after The Great Depression in 1928. The Great Recession is a global economic scenario that is still felt today after the international financial crisis precipitated by the bankruptcy of the traditional American investment bank Lehman Brothers, founded in 1850. In the domino effect, other major financial institutions broke down in the process also known as "Subprime crisis". George Soros (2008) says that "we are in the middle of a financial crisis not seen since the crisis of 1929" and states that this crisis could, in theory, have been avoided.

In order to avoid a collapse, the US government re-established the Fannie Mae and Freddie Mac real estate credit agencies, which were privatized in 1968, which were then indefinitely controlled by the government, injecting $ 200 billion into the two agencies, considered the largest operation financial bailout made by the US government until then. In Europe, Germany, France, Austria, the Netherlands and Italy have announced packages totalling 1.17 trillion euros ($ 1.58 trillion) to safeguard their financial systems. Eurozone GDP fell by 1.5% in the fourth quarter of 2008, compared to the previous quarter, the largest contraction in the history of the euro area economy.

The year 2009 is the beginning of the European debt crisis. Several Eurozone member states (Greece, Portugal, Ireland, Spain and Italy) were unable to repay or refinance their government debt or to bail out over-indebted banks under their national supervision without the assistance of third parties like other Eurozone countries, the European Central Bank (ECB), or the International Monetary Fund (IMF).

The impact of this crisis in the commodity markets weren't symmetrical to the commodities studied in this research. Each commodity had a different behaviour with the development of this crisis that impacted differently the countries. In the case of the crude oil there is a big increase of the value from the beginning of 2008 to July of same year, leaving this commodity to hit the highest value ever. After that period the prices of crude oil decreased sharply.

In the precious metals, gold hit the highest value in September 2011 and silver in April 2011. This increase comes according with the fact that these commodities are considered as safe assets, so investors tend to invest on this type of commodities in times of crisis.

Observing the data used to run the tests in this research in this period, lots of cycles in the values of these commodities are showed, that can be justified by the monetary policies of the main central banks to try to control the economical grow and the inflation, that lead to so many changes in the prices of the commodities.

3. Data and Methodology

3.1. Research Questions

As mentioned before in the introduction, this study aims to observe the relationship between the commodities and US Dollar Index. According to Radomski (2016), Hawkes (2015) and Hameed and Arshad (2008), sometimes it can be observed a relationship between US Dollar/Crude Oil as driver of the value of other commodities.

So with the results observed in the theoretical support written in the first part and the empirical results obtained in the econometrical tests performed in the third part, this research tries to find an answer to the questions:

- Does the nexus between oil prices, exchange rate and commodity prices, differ due to the type of the commodity under analysis, or do they interact?
- Why the effect of oil and dollar should differ because of the different commodity type?

The first question can be justified with the empirical results provided in the econometrical tests from the third part. This question could be easily answered with a simple OLS regression, but that regression would just give us a possible unidirectional relationship between variables. As the aim of this study is not excusably to have these commodities (Gold, Silver, Agriculture, Fats and Oils, Metals and Minerals) as exogenous variables just depending on the two variables (US Dollar index and Crude oil) as endogenous. That's the main reason why the econometrical test used to try to answer this question was a Vector Error Correction Model, because this model treats all the variables as exogenous and as endogenous, simultaneously, making it possible to answer the questions above, and go more abroad like observing how the US Dollar index and the six different commodities interact between each other. Many other studies related with this one such as Byrne, Fazio and Fiess (2013), Rezitis (2015), Belke, Bordon and Hendricks (2010), Seyyedi (2017), Hammoudeh, Khuong Nguyen, and Sousa (2014), Harvey, Kellard, Madsen and Wohar (2017), Akram (2008), Hammoudeh, Nguyen and Sousa (2016) and Frankel (2013) use a Vector Autoregressive model.

The second question can be answered with more support from the theoretical framework presented on this research. The results from the econometric tests, can prove that there is some relationship between the variables, but is not enough to give plausible explanations. The main objective of this question is to give possible causes for some relationships that were observed. As the results of this relationships can be quite different from period to period, and as this econometrical test does not includes explicit macroeconomic variables, it is necessary to explain these relationships based on some theories. For example, Gold and Silver show similar patterns in times of crisis provided their similarities as safe assets. Crude oil and Metals are more vulnerable to macroeconomic trends, because these depend on the demand of countries like China or USA for these commodities. Agriculture and Fats are more affected by microeconomic variables, such as costs of production. These commodities have less elastic demand than the other ones because, even in times of crisis the citizens need to eat to be able to have a healthy life, so in times of crisis the incomes of the families can decrease but the consumption of food cannot decrease substantially. So it is interesting to gather possible explanations for these different types of relationships.

3.2. Data

The data used in this study is from the Quandl and Investing database and comprises monthly data from January, 1990 to December, 2015 with a total of 312 observations per product. This period is going to be split in three different periods, the first one running from January 1990 to December 1999 with 120 observations, the second from January 2000 to December 2007 and the third and last period from January 2008 to December 2015, which each one of the last periods having 96 observations. The variables used are the US Dollar Index, Crude Oil Brent, Metals and Minerals, Agriculture, Fats and Oils, Gold and Silver trading prices.

According to Chuck Kowalski (2016), commodity traders need to keep a close eye on the value of the dollar. One of the best ways to monitor the dollar is to watch the price quotes of the Dollar Index traded on the ICE Futures Exchange. This futures contract is an index that values the dollar against a group of other major currencies around the world like the euro, yen, British pound, and other foreign exchange instruments. The US Dollar Index is a measure of the value of the US Dollar relative to a basket of foreign currencies. It is calculated as a weighted geometric mean of Dollar´s value against Euro, Japanese Yen, Pound Sterling, Canadian Dollar, Swedish Krona and Swiss Franc. In the futures markets, one contract is traded as 1000$ x Index Value. As the US dollar is the benchmark pricing mechanism for most commodities, the inclusion of this variable on this study seems right.

According to Martén and Jiménez (2015) Brent crude oil is the primary benchmark for international oil prices today, serving as the price reference for roughly two-thirds of the world's traded-oil volume. Following Sun, Lu, Yue and Li (2016) oil is one of the key energies for industry production, and crude oil prices play a crucial role in affecting production cost, investment and consumption. As a result, higher oil prices may lead to higher inflation levels and global economic downturn. The inclusion of this variable is related with the importance that this one can have in world inflation. The data related with this variable is measured in US dollars per barrel, and is in spot prices.

According to Radomski (2014) there seems to be a relatively strong relationship between gold and oil prices but not between gold and oil returns. The strength of the relationship between gold and oil coincides with high or low gold returns. The data is from the London (UK) afternoon fixing, being the average of daily rates of gold price and is measured in US dollars per ton.

Some of the commodities used in this study follow common patterns. Also, Radomski (2016) evidences this stating that we would see that on average, price of silver increases along with the price of gold. After this statement we also wanted to test the relationship between the US Dollar index and that of the crude oil in the price of Silver. As is postulated by this author before, that Gold and Crude oil have a relationship, it is interesting to test the relationship of the Crude oil and US Dollar index in the price of silver. The data is measured in US Dollars per tons and is from the New York Silver Price, USA.

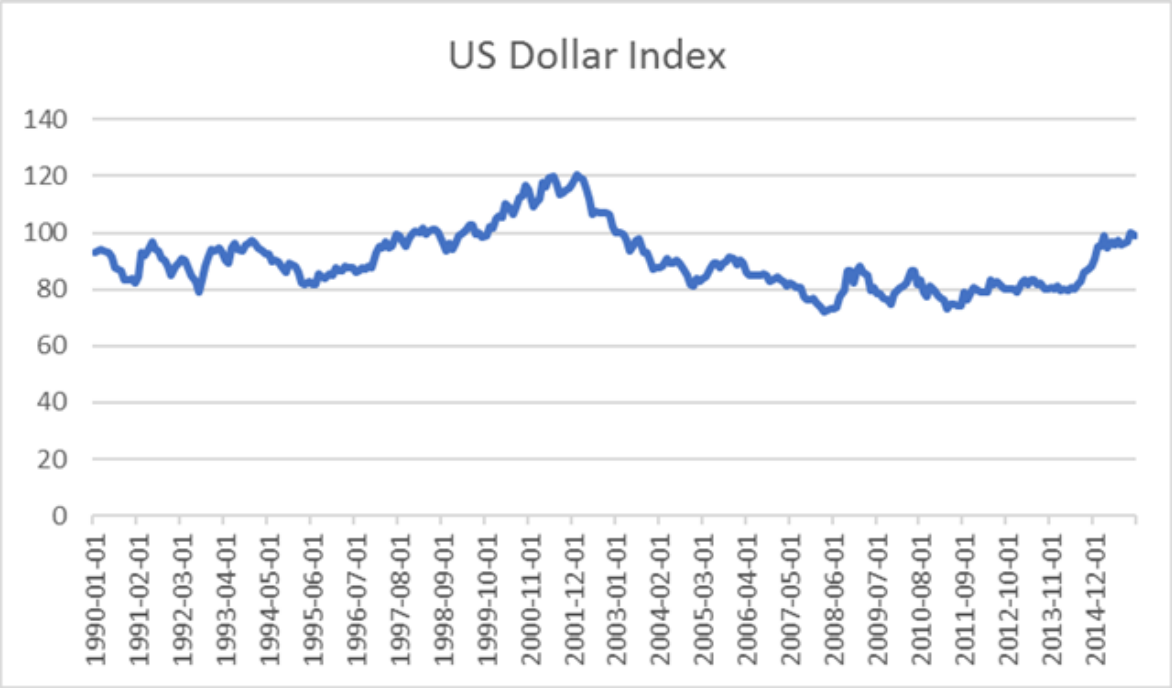
Moreover, Hawkes (2015) argues that a simple calculator will easily demonstrate that lower fuel prices equate to lower production costs on the farm, not only input costs but the cost of transporting the crop to market. Many other authors, postulate the same, that's why it is interesting to study this relationship between the Agriculture commodities and US Dollar index and Crude oil. The data is from the World Bank Agriculture Index. The Agriculture commodities in this group are beverages, food, and agricultural raw materials.

In Hameed and Arshad (2008) the results of the Granger causality tests show that in the long-run there was a unidirectional relationship between petroleum price and the prices of each of the four vegetable oils, i.e., palm, rapeseed, soybean and sunflower oils. Given that the authors find out this relationship, we also wanted to test this association. The data of the Fats and Oils is from the World Bank Oils & Meals Index. The fats and oils included in this group are coconut, groundnut, palm, soybean oils.

Akram (2008), as mention before, said that the oil prices as well as metal prices tend to display overshooting behaviour in response to interest rate changes. So metals are also interesting to study under the present setting. The data about the Metals and Minerals is from the World Bank Metals & Minerals Index. On this group is included the following metals and minerals: aluminium, copper, iron ore, lead, nickel, tin, and zinc.

In the following we will provide a visual analysis of the temporal evolution of each of the series used in the study to see if there are visible evolution patterns.

Figure 5 - US Dollar Index



The US dollar index as representative of exchange rates shows a clear increase between 1999 and 2002 having then followed a decreasing pattern and only in 2014 it started to be close to 100. It is also evident a decrease in 2008 in this index, being much more evident in the case of crude oil with a sudden drop. Crude oil reached its maximum value before 2008, with a sudden drop and increased again until 2011, becoming stable afterwards. However, from 2013 onwards it is observed a decreasing pattern again with respect to oil prices.

Turning attention to gold and silver we observe similar patterns among these two variables and we find clear fundament for the fact that both commodities are considered safe as haven in turbulent times. This is due to the fact that while most of the other series have sudden drops in 2008, these two have seen their prices increasing as never during the 2008-2011 period, having afterwards followed the decreasing pattern of crude oil.

Figure 6 - Crude Oil

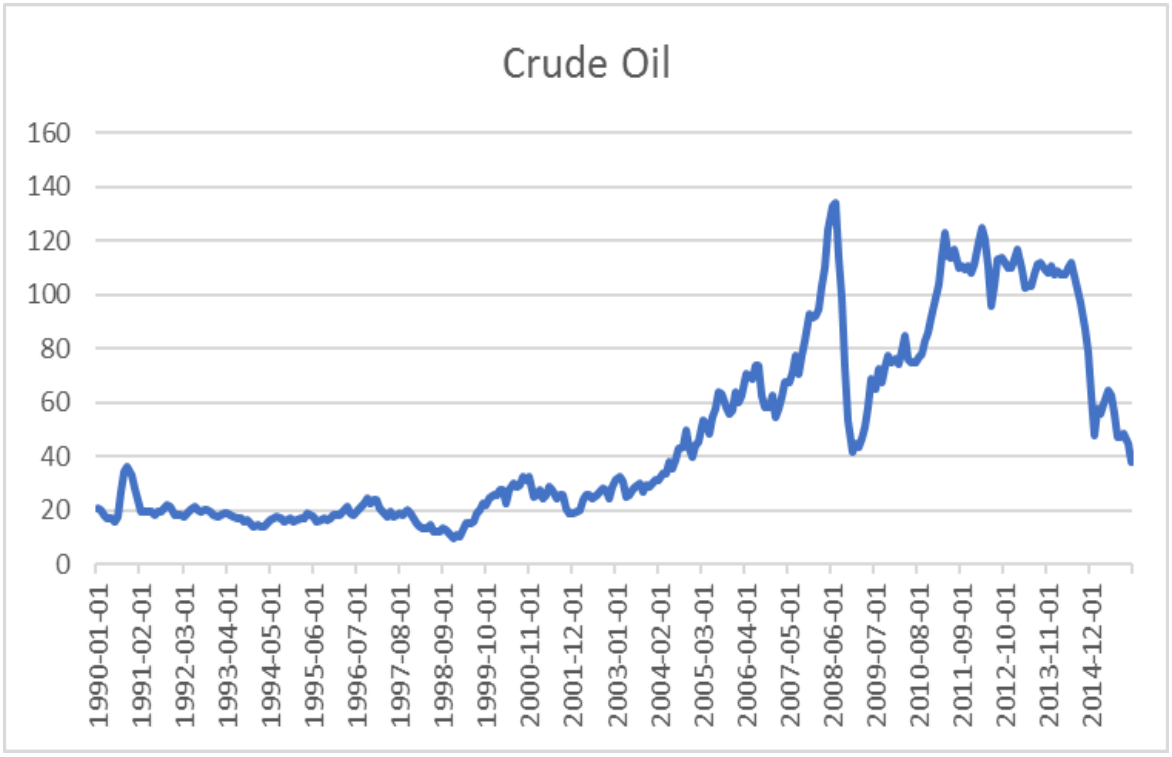


Figure 7 - Gold

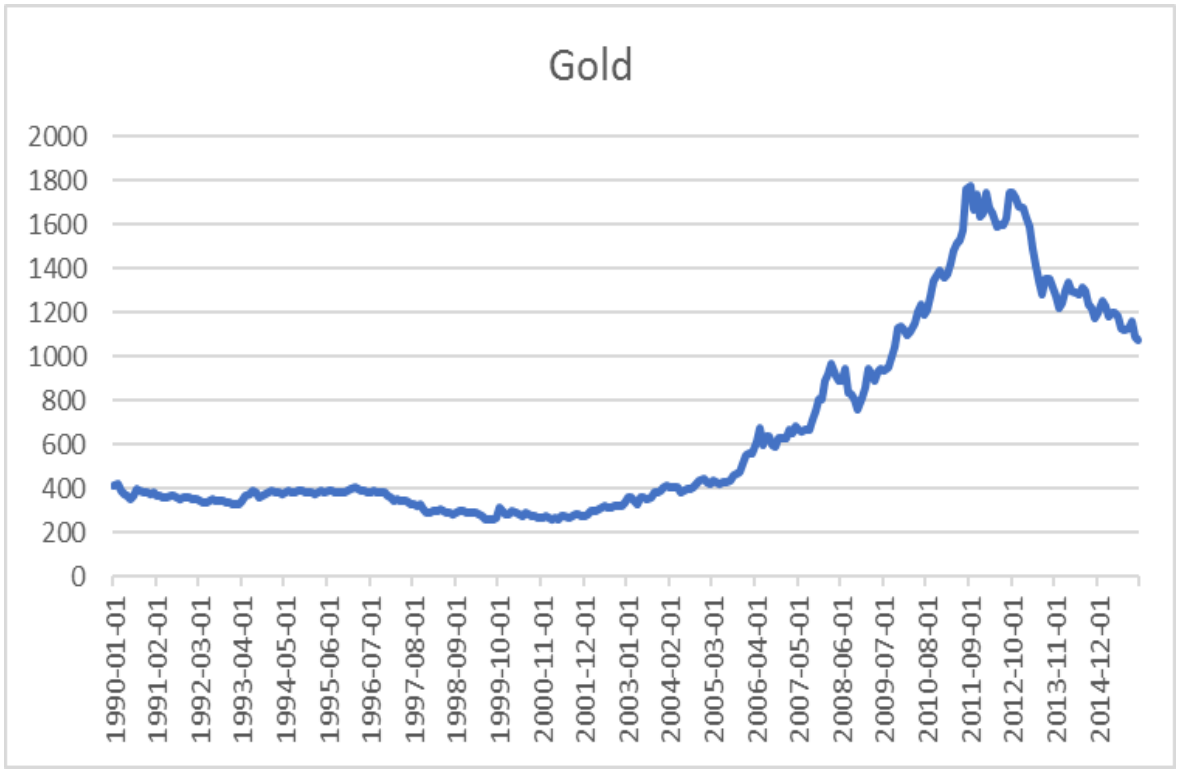


Figure 8 - Silver

Figure 9 - Agriculture

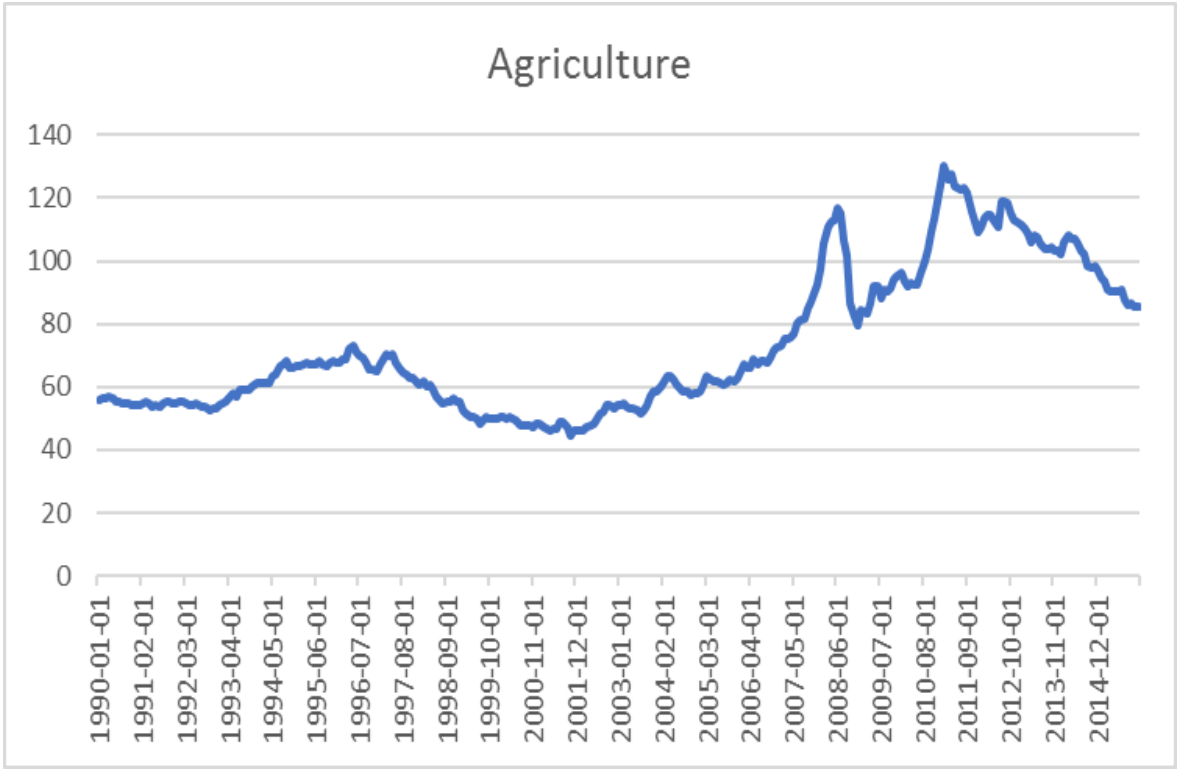


Figure 10 - Fats and Oils

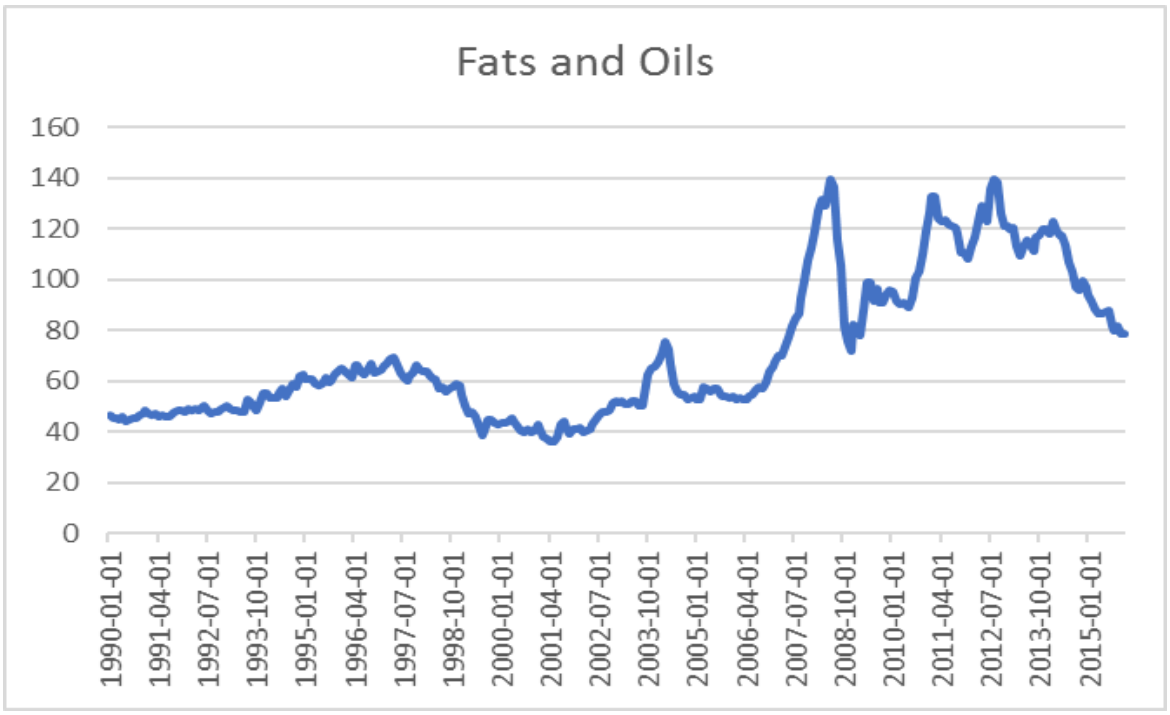
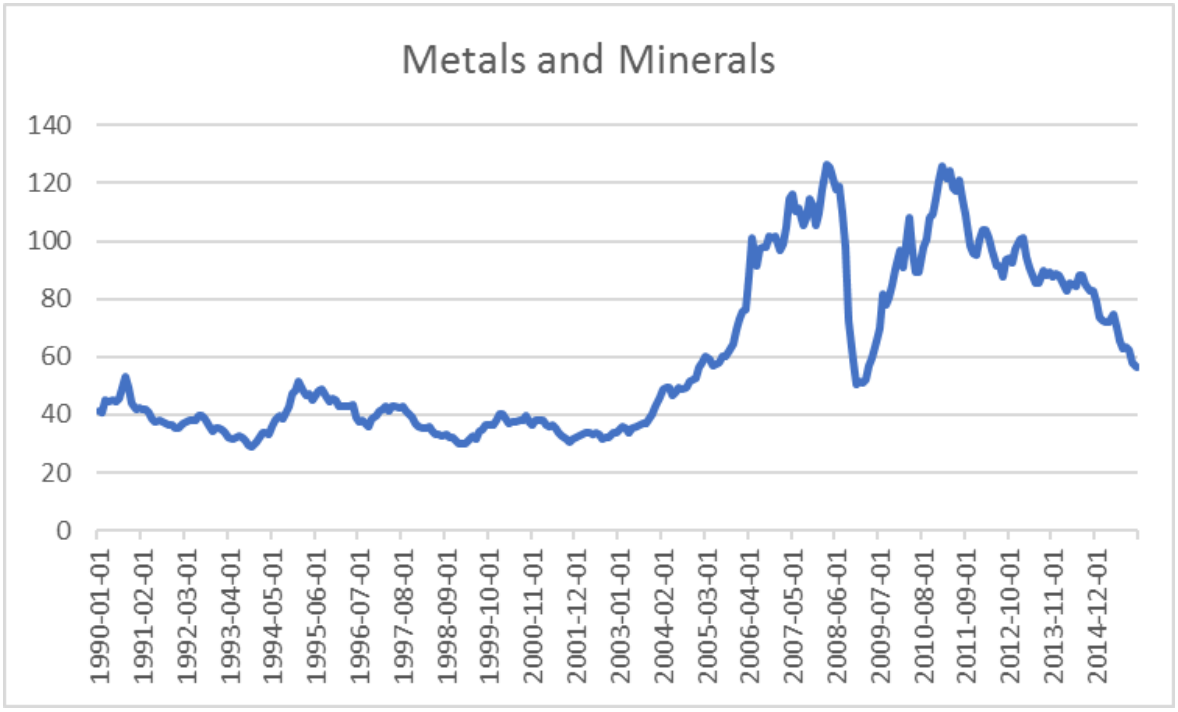


Figure 11 - Metals And Minerals



Agriculture, fats and oils and metals and minerals all seem to have a similar behaviour through time. That is their prices increased a lot from 2006 until the beginning of 2008, then they suddenly dropped and start increasing again at the mid-2009. They then turned to become less volatile, but after 2013 we start observing a decreasing pattern of these commodities again which was still observed at the end of our sample period. More detailed analysis is provided in the section discussing the great event occurring for distinct periods of time.

3.3. Methodology

This section discusses methodological principles used in this work. First the theoretical explanations of the econometrical methods that are going to be used are provided and second the models that are going to be employed in the analysis of the nexus between US Dollar, Oil price and Commodity index are presented.

3.3.1. Stationary and Non-Stationary Time Series

Gujarati (2011) refers that a time series is said to be stationary if its mean and variance are constant over time and the value of the covariance between the two periods depends only on the distance or gap or lag between the two times period and not the actual time at which the covariance is computed. However, many time series, more exactly typically financial time series, often display some kind of systematic upward or downward movement through time and, as a consequence, are not stationary.

Stationary and non-stationary time series demand different approaches, otherwise forecast studies will predict, most probably, inconsistent conclusions and unrealistic or divergent results. A time series with a trend is one of the most usual examples of non-stationary time series.

3.3.2. Augmented Dickey-Fuller test

To test the stationarity of a time series we usually use the reference test or the Augmented Dickey-Fuller test. Dickey and Fuller proposed three alternative regression equations, based on a simple AR(1) model, that can be used for testing for the presence of unit root as synonymous of non-stationarity.

These equations are:

$$\Delta yt = \delta yt - 1 + \mu t \quad (1)$$

$$\Delta yt = \alpha + \delta yt - 1 + \mu t \quad (2)$$

$$\Delta yt = \alpha + \gamma t + \delta yt - 1 + \mu t \quad (3)$$

Where (3) includes a time trend and a constant and (2) only includes a constant. The DF test is a t-test, but not a conventional one, so we must use nonstandard critical values which were first calculated by Dickey and Fuller, and later by other authors.

Dickey and Fuller extended their test procedure including extra lagged terms of the dependent variable. This allows for the testing of unit roots in autoregressive processes that are of order higher than one. The three possible equations of the test are the same but now they all include the additional term:

$\sum_{i=1}^{P} \beta_i \cdot \Delta y_{t-1}$.

So we have the Augmented Dickey-Fuller test, with the null hypotheses defined as Ho: there is a unit root.

This test may be used with all the variables and, when non-stationarity is observed, it may be used again to test their first differences, second differences, and so on. We say that a variable is integrated of order 1, or simply I (1) when the series is nonstationary in level but his first differences are stationary.

3.3.3. Cointegration

If we have two or more non-stationary time series, that become stationary when differenced, such that some linear combination of those series is stationary, then we say that they are cointegrated. That means that those series show some kind of long-run relationship.

In other words, we say that two I (1) time series xt and yt are cointegrated, if there is a β such that $zt = yt - \beta \times xt$ is stationary.

3.3.4. Johansen

To test the existence of cointegration between the variables, it should be used, at least, one of three kind of tests: the Engle-Granger cointegration test developed by Engle and Granger (1987), the Philips-Ouliaris reference test, presented by these authors, or most recently the Johansen cointegration test, presented by Johansen and Juselius in 1990.

The main advantage of the Johansen test, regarding the others tests, consists in the determination of the number of cointegrating vectors that exists among the studied variables, when these variables are cointegrated, and provides estimates of all cointegrating vectors. As Dwyer (2014) refers, the Johansen test can be seen as a multivariate generalization of the ADF test because it is the study of the linear combination of variables for unit roots. It must be noticed that if there are k variables, each with unit roots, there are $k - 1$ possible cointegrating vectors, and if there are k variables and k cointegrating vectors, then we may conclude that the variables do not have unit roots.

Johansen proposes two different tests: the trace test and the λmax test. The trace test is based on the log-likelihood ratio $ln[Lmax\ (r)\ /\ Lmax\ (k)]$ and is conducted sequentially for $r = k - 1,\ldots,1,0$. This test tests the null hypothesis that the cointegration rank is equal to r against the alternative hypothesis that the cointegration rank is equal to *k*.

Asteriou (2007) refers four steps in Johansen test approach. Step 1: test the order of integration of all variables; step 2: set the appropriate lag length of the model. This may be done using some criteria that we will see next; step 3: choose the appropriate model that correlates the variables; step 4: determine the rank of Π or the number of cointegrating vectors, using λmax test or trace test.

3.3.5. Akaike Information Criterion

We must compare the goodness of fit data-models, to decide about the number of lags which must be used in the model. We may use some criteria provided by GRETL software, for instance: the Akaike Information Criterion (AIC), the Finite Prediction Error (FPE), the Schwarz Baysean Criterion (SBC) and the Hannan and Quin Criterion (HQC).

Ideally the chosen model should be the one which minimizes all these criteria simultaneously. However, sometimes the results are contradictory, and in the analysis of time series the statistic most commonly used is AIC. It is defined by:

$$AIC = (RSS/n) \times e\text{^}(2k/n) \quad (4)$$

where we must recall that $RSS = \Sigma t = 1$ û$t2$ and ût represents the difference between the actual yt and the fitted values predicted by the regression equation.

3.3.6. VAR (Vector Autoregressive) VECM (Vector Error Correction)

We may model a time series data using some models. The simplest one is the autoregressive of order one model AR(1), which is given by:

$$yt = \alpha . yt - 1 + \mu t \quad (5)$$

Where $| \alpha | < 1$ and ut is a Gaussian error term. This model assumes that the actual value of y_t is determined by its own value in the precedent period.

The model becomes more complex when we have more than one time series, with the actual values of each one influenced not only by its own past values, but also by the past values of all the other variables. In this case we can use a VAR model.

Pfaff (2006) defines a Vector Autoregressive model as a set of k endogenous variables written in the form:

$$yt = Ai\ yt - 1 + ... + Ap\ yt - 1 + \mu t \quad (6)$$

In this equation, Ai is the $(k\ x\ k)$ matrix of coefficients and μt is a k-dimensional lagged process of order p, with $E (\mu t) = 0$.

$$yt = A1xt + \Sigma j = 1\ Bjyt - j + \Sigma j = 1\ Cjxt - j + \mu 1t \quad (7)$$

$$yt = A2yt + \Sigma j = 1\ Djxt - j + \Sigma j = 1\ Ejyt - j + \mu 2t \quad (8)$$

where we assume that $u1t$ and $u2t$ are uncorrelated white-noise error terms, called impulses or shocks. In this form we may see that yt and xt are affected not only by their past values, but each variable is affected, too, by the other variable past and current values.

Although the number of lagged values of each variable can be different, we usually use the same number (p) of lagged terms in each equation.

A VAR model can be reformulated as an error correction model, when cointegration relationships are found, considering the following relation:

$$\Delta yt = \Pi\ yt - p + \Gamma 1\ \Delta yt - 1 + ... + \Gamma p - 1\ yt - p + 1 + \mu t \quad (9)$$

With $\Pi = \alpha . \beta$. The matrix α is the loading matrix (includes the speed of adjustment to equilibrium coefficients) and the coefficients of the long-run relationships are contained in β', and the Γi matrices measure the effect of transitory impacts.

The $(k\ x\ k)\ \Pi'$ matrix contains the error correction terms. The dimensions of α and β are k and r, respectively, and r is the number of long-run relationships existing between the variables yt.

The general case of VECM including all the options is:

$$\Delta y_t = \alpha \begin{bmatrix} \beta \\ \mu_1 \\ \delta_1 \end{bmatrix} \times [y_{t-1} \quad 1 \quad t] + \Gamma_1 \Delta y_{t-1} + \ldots + \Gamma_{k-1} y_{t-k-1} + \mu_2 + \delta_2 t + \mu_t \quad (10)$$

where the terms represent: μ_1: intercept in the cointegrated equation (CE), $\delta 1$: trend in CE; $\mu 2$: intercept in VAR; $\delta 2$: trend in VAR. GRETL provide us with five distinct models depending on the existence of intercept and trend in CE or in VAR; the model with trend in CE and in VAR is only theoretical (non realistic) so, in practice, it is rarely adopted.

In the VECM model, the rank (or trace) of matrix Π' has the following lecture, concerning the cointegration of the variables: if $r = 0$ there is no cointegration (we cannot use VECM, only VAR in first differences); if

$0 \lt r \lt k$ there are r cointegrating vectors (we can use VECM); if $r = k$ all the variables are already stationary, so we may use VAR on level data.

3.3.7. Forecast Error Variance Decomposition (FEVD)

According to Lütkepohl (2007) forecast error variance decomposition (FEVD) is used to aid in the interpretation of a vector auto regression (VAR) model once it has been fitted. The variance decomposition indicates the amount of information each variable contributes to the other variables in the auto regression. It determines how much of the forecast error variance of each of the variables can be explained by exogenous shocks to the other variables.

3.4. Models

In the related studies, usually the econometric method used is the VAR like Byrne, Fazio and Fiess (2013), Rezitis (2015), Belke, Bordon and Hendricks (2010), Seyyedi (2017), Hammoudeh, Khuong Nguyen, and Sousa (2014), Harvey, Kellard, Madsen and Wohar (2017), Akram (2008), Hammoudeh, Nguyen and Sousa (2016), Frankel (2013).

As the main aim of this study is to study the relations between US Dollar Index, Crude Oil, Gold, Silver, Agriculture, Fats and Oils, Metals and Minerals, in this study the econometric method that suits better is the VECM because there was identification of cointegration between the variables in the Johansen cointegration tests.

The model is expressed in the following form:

$$\begin{bmatrix} rus_t \\ roil_t \\ rgold_t \\ rsilver_t \\ ragriculture_t \\ rfatsandoils_t \\ rmetals_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \\ \alpha_7 \end{bmatrix} + \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \\ \beta_6 \\ \beta_7 \end{bmatrix} \begin{bmatrix} rus_{t-1} & roil_{t-1} & rgold_{t-1} & rsilver_{t-1} & ragriculture_{t-1} & rfatsandoils_{t-1} & rmetals_{t-1} \\ rus_{t-1} & roil_{t-1} & rgold_{t-1} & rsilver_{t-1} & ragriculture_{t-1} & rfatsandoils_{t-1} & rmetals_{t-1} \\ rus_{t-1} & roil_{t-1} & rgold_{t-1} & rsilver_{t-1} & ragriculture_{t-1} & rfatsandoils_{t-1} & rmetals_{t-1} \\ rus_{t-1} & roil_{t-1} & rgold_{t-1} & rsilver_{t-1} & ragriculture_{t-1} & rfatsandoils_{t-1} & rmetals_{t-1} \\ rus_{t-1} & roil_{t-1} & rgold_{t-1} & rsilver_{t-1} & ragriculture_{t-1} & rfatsandoils_{t-1} & rmetals_{t-1} \\ rus_{t-1} & roil_{t-1} & rgold_{t-1} & rsilver_{t-1} & ragriculture_{t-1} & rfatsandoils_{t-1} & rmetals_{t-1} \\ rus_{t-1} & roil_{t-1} & rgold_{t-1} & rsilver_{t-1} & ragriculture_{t-1} & rfatsandoils_{t-1} & rmetals_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \\ \varepsilon_6 \\ \varepsilon_7 \end{bmatrix} \quad (11)$$

4. Empirical Results

4.1. Unit Root test

In order to avoid spurious regression problems, we will begin this part of the study with the unit root test to see if the variables are stationary. The variables were not stationary as it was shown in the previous chapter of this study so the ADF test was done with the first differences to test the stationarity of the variables.

Table 1 - ADF test with the Value and the First Differences, 1990-1999

Augmented Dickey Fuller		
Variables	**Value**	**Return**
US Dollar Index	0,234	4,12E+08
Crude Oil	0,001747	6,81E+10
Gold	0,5832	4,70E+13
Silver	0,1937	3,66E+15
Agriculture	0,777	1,49E+06
Fats and Oils	0,7548	5,82E+16
Metals and Minerals	0,2125	1,49E+10

Note: The column Values are the values without first differences and in the column Return they have the first differences

Table 2 - ADF test with the Value and the First Differences, 2000-2007

Augmented Dickey Fuller		
Variables	**Value**	**Return**
US Dollar Index	0,9029	6,95E+09
Crude Oil	0,9957	2,20E+14
Gold	1	8,86E-04
Silver	0,9983	2,40E+05
Agriculture	1	1,75E+07
Fats and Oils	0,9998	5,84E+08
Metals and Minerals	0,8501	7,50E+09

Note: The column Value are the values without first differences and in the column Return they have the first differences values

Table 3 - ADF test with the Value and the First Differences, 2008-2015

Augmented Dickey Fuller		
Variables	**Value**	**Return**
US Dollar Index	0,9989	2,21E-03
Crude Oil	0,3019	2,67E+06
Gold	0,4918	1,27E-02
Silver	0,5136	4,83E+09
Agriculture	0,3848	9,46E+07
Fats and Oils	0,1627	3,75E+05
Metals and Minerals	0,168	6,84E+06

Note: The column Value are the values without first differences and in the column Return they have the first differences values

With the inclusion of the returns (log first differences) on the ADF test, the variables become stationary. The spurious regression problem is solved, and we can proceed with the calculations. To continue with the calculations now we proceed to the test of the number of lags that we should use on the model.

4.2. VAR Lag Selection

To see how much lags should be used in the models runned on GRETL the Var Lag selection, with the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC) and Hannan–Quinn Information Criterion (HQC) was applied.

Table 4 - VAR Lag Selection, 1990-1999

VAR lag selection					
Lags	**Loglik**	**p(LR)**	**AIC**	**BIC**	**HQC**
1	1594,86613		***-27,727318***	***-26,360347***	***-27,172778***
2	1629,98732	0,02491	-27,477249	-24,91418	-26,437488
3	1652,0803	0,6683	-26,992438	-23,23327	-25,467454
4	1702,12801	0,00002	-27,011315	-22,056049	-25,00111
5	1728,67125	0,31961	-26,606689	-20,455323	-24,111262
6	1768,5805	0,00354	-26,442892	-19,095427	-23,462243
7	1836,29842	0	-26,780152	-18,236588	-23,31428
8	1901,5103	0	-27,072258	-17,332595	-23,121164

Table 5 - VAR Lag Selection, 2000-2007

VAR lag selection					
Lags	**Loglik**	**p(LR)**	**AIC**	**BIC**	**HQC**
1	1269,14286		***-27,571429***	***-25,994942***	***-26,936302***
2	1301,85833	0,05827	-27,201326	-24,245413	-26,010463
3	1336,47782	0,02997	-26,874496	-22,539157	-25,127897
4	1365,06468	0,19758	-26,410561	-20,695795	-24,108225
5	1414,26168	0,00004	-26,415038	-19,320846	-23,556966
6	1456,12171	0,00147	-26,252766	-17,779148	-22,838958
7	1499,63047	0,00067	-26,127965	-16,274921	-22,158421
8	1590,2773	0	-27,074484	-15,842014	-22,549204

Table 6 - VAR Lag Selection, 2008-2015

VAR lag selection					
Lags	**Loglik**	**p(LR)**	**AIC**	**BIC**	**HQC**
1	1239,44087		***-26,896383***	***-25,319896***	***-26,261256***
2	1287,20066	0,00008	-26,868197	-23,912284	-25,677334
3	1318,00778	0,10658	-26,454722	-22,119383	-24,708123
4	1351,30171	0,04791	-26,097766	-20,383	-23,79543
5	1385,23997	0,03828	-25,755454	-18,661262	-22,897382
6	1445,80412	0	-26,018275	-17,544657	-22,604467
7	1514,51595	0	-26,466272	-16,613227	-22,496727
8	1582,31698	0	-26,893568	-15,661097	-22,368287

In the three periods, and in the three tests (AIC, BIC, HQC), the number of lags that should be used in the model were one as we can see in the values written in the red colour in the tables.

4.3. Johansen Cointegration test

This test is used to choose which model will suit better the variables relationship, the VAR or the VECM. The Johansen Cointegration test give us the relationship between the variables by the Unrestricted Cointegration Rank Test (Trace) and the Unrestricted Cointegration Rank Test (Maximum Eigenvalue) as is going to be shown in the next tables.

Table 7 - Unrestricted Cointegration Rank Test (Trace), 1990-1999

Unrestricted Cointegration Rank Test (Trace)			
Hypothesized No. Of CE	**Eigenvalue**	**Trace Statistic**	**P-value**
None	0,60119	478,43	0
At most 1	0,49882	369,96	0
At most 2	0,47404	288,45	0
At most 3	0,45583	212,63	0
At most 4	0,35791	140,83	0
At most 5	0,34585	88,551	0
At most 6	0,2782	38,47	0

Table 8 - Unrestricted Cointegration Rank Test (Maximum Eigenvalue), 1990-1999

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)			
Hypothesized No. Of CE	**Eigenvalue**	**Max-Eigen Statistic**	**P-value**
None	0,60119	108,47	0
At most 1	0,49882	81,513	0
At most 2	0,47404	75,818	0
At most 3	0,45583	71,803	0
At most 4	0,35791	52,277	0
At most 5	0,34585	50,081	0
At most 6	0,2782	38,47	0

Table 9 - Unrestricted Cointegration Rank Test (Trace), 2000-2007

Unrestricted Cointegration Rank Test (Trace)			
Hypothesized No. Of CE	**Eigenvalue**	**Trace Statistic**	**P-value**
None	0,72658	447,21	0
At most 1	0,55088	324,02	0
At most 2	0,50387	247,97	0
At most 3	0,47068	181,39	0
At most 4	0,41897	120,95	0
At most 5	0,35219	69,372	0
At most 6	0,25627	28,127	0

Table 10 - Unrestricted Cointegration Rank Test (Maximum Eigenvalue), 2000-2007

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)			
Hypothesized No. Of CE	**Eigenvalue**	**Max-Eigen Statistic**	**P-value**
None	0,72658	123,19	0
At most 1	0,55088	76,044	0
At most 2	0,50387	66,588	0
At most 3	0,47068	60,435	0
At most 4	0,41897	51,58	0
At most 5	0,35219	41,245	0
At most 6	0,25627	28,127	0

Table 11 - Unrestricted Cointegration Rank Test (Trace), 2008-2015

Unrestricted Cointegration Rank Test (Trace)			
Hypothesized No. Of CE	**Eigenvalue**	**Trace Statistic**	**P-value**
None	0,75595	438,82	0
At most 1	0,53011	304,83	0
At most 2	0,51981	233,08	0
At most 3	0,42088	163,39	0
At most 4	0,3907	111,5	0
At most 5	0,32375	64,434	0
At most 6	0,24954	27,271	0

Table 12 - Unrestricted Cointegration Rank Test (Maximum Eigenvalue), 2008-2015

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)			
Hypothesized No. Of CE	**Eigenvalue**	**Max-Eigen Statistic**	**P-value**
None	0,75595	133,99	0
At most 1	0,53011	71,75	0
At most 2	0,51981	69,69	0
At most 3	0,42088	51,893	0
At most 4	0,3907	47,067	0
At most 5	0,32375	37,163	0
At most 6	0,24954	27,271	0

According to the tests, there are at least six relations of cointegration identified in each different period, so in this study the regression is going to be runned with the Vector Error Correction Model (VECM) instead of the Vector Autoregression (VAR).

The next tables are going to give the results of the VECM and the FEDV. In these tables there is the variables RUS are the returns of the US Dollar Index, the ROIL is the return of the Crude Oil commodity, the RGOLD is the return of the Gold commodity, the RSILVER is the return of the Silver commodity, the RAGRICULTURE is the return of the Agriculture commodity group, RFATSANDOILS is the return of the Fats and Oils commodity group and the RMETALS is the return of Metals and Minerals commodity group.

4.4. VECM

The results of the VECM are going to be presented in the next tables by the respective periods, to measure the impact that each variable has on value of the other variable. Tables present coefficient values and probability values (p-values) in brackets. Each table presents the multivariate regressions simultaneously as this is a useful characteristic of the VECM model.

Table 13 - VECM, 1990-1999

VECM							
	RUS	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSOILS**	**RMETALS**
C	0,0012385 [0,5975]	0,0038725 [0,6133]	-0,0025106 [0,3474]	-0,0009013 [0,8469]	-3,21E-06 [0,9845]	0,0001066 [0,9735]	-0,0007425 [0,8272]
RUS(-1)	0,0728551 [0,4631]	-0,0917937 [0,7769]	0,0344965 [0,7598]	0,160957 [0,4157]	-0,103389 [0,1426]	-0,0204866 [0,8803]	0,0801624 [0,5777]
ROIL(-1)	0,0463507 [0,1246]	0,100632 [0,3058]	-0,0178744 [0,6007]	-0,0246924 [0,6795]	-0,0199576 [0,3480]	-0,0459571 [0,2655]	0,0718558 [0,1010]
RGOLD(-1)	-0,136471 [0,1611]	0,0362852 [0,9088]	***0,223266*** ***[0,0449]***	0,238233 [0,2187]	0,00246208 [0,9713]	0,0520496 [0,6955]	0,0214794 [0,8786]
RSILVER(-1)	0,0524907 [0,3462]	-0,105917 [0,5601]	-0,0461597 [0,4661]	-0,0377083 [0,7335]	-0,0258686 [0,5112]	-0,0445699 [0,5593]	***-0,170646*** ***[0,0364]***
RAGRICULTURE(-1)	-0,156792 [0,3217]	0,240715 [0,6408]	***-0,589338*** ***[0,0014]***	***-0,731034*** ***[0,0217]***	***-0,582841*** ***[8,82E-07]***	***-0,573348*** ***[0,0092]***	0,146689 [0,5222]
RFATSOILS(-1)	0,0924935 [0,2576]	***0,44387*** ***[0,0975]***	***0,177912*** ***[0,0570]***	***0,271857*** ***[0,0959]***	***0,170707*** ***[0,0037]***	***0,368672*** ***[0,0013]***	0,144966 [0,2216]
RMETALS(-1)	-0,0180651 [0,7954]	***-0,508597*** ***[0,0272]***	0,127588 [0,1096]	***0,274576*** ***[0,0499]***	0,0387581 [0,4322]	0,0840887 [0,3797]	-0,019952 [0,8435]

Note: The values without parentheses are the coefficient values and in parentheses are the p-values. The values written with the red colour are the values that are statistically significant at 5% of significance.

In accordance to table 13 results, for the period 1990-1999, there are no significant variables affecting the exchange rate, but oil prices seem to be statistically and significantly affected by the lagged values of fats oil and metal returns, positively and negatively, respectively. In turn, gold returns seem to be positively moved with their own lag values and also by lagged fats oil returns, being negatively influenced by lagged agriculture returns. It also seems to exist a negative relationship between silver and agriculture returns, but there is evidence of a positive and significant relationship between silver which is affected by lagged fats oils and metals returns. On the other hand, we have agriculture being negatively and significantly explained by its own lagged returns and there seems to exist a positive influence of lagged fats oil returns over agriculture.

Fats oil are also negatively affected by lagged agriculture returns and by its own lagged values, whereas metals returns seem to be only negatively and significantly impacted by movements occurring in lagged silver returns. In this period fats and oils were the exogenous variable that had more statistically significant values in more endogenous variables such as Crude oil, Gold, Silver, Agriculture at the same time. His impact was positive in all the variables, an increase in the value of Fats and Oils increase positively the value of the commodities mentioned.

Table 14 - VECM, 2000-2007

VECM							
	RUS	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSOILS**	**RMETALS**
C	***-0,00434179 [0,0984]***	0,00930434 [0,3778]	***0,011534 [0,0071]***	0,0106415 [0,1140]	0,00205908 [0,3741]	0,0012670 [0,7884]	***0,0110546 [0,0197]***
RUS(-1)	-0,0377949 [0,7625]	-0,278222 [0,5821]	-0,228027 [0,2587]	-0,123251 [0,7009]	***-0,352499 [0,0020]***	***-0,601168 [0,0094]***	-0,150899 [0,5004]
ROIL(-1)	0,00902801 [0,7614]	***0,225063 [0,0637]***	0,0522065 [0,2765]	0,0695437 [0,3629]	-0,0201783 [0,4450]	***-0,0932747 [0,0862]***	***0,109528 [0,0420]***
RGOLD(-1)	-0,120908 [0,2175]	0,434948 [0,2718]	0,0435811 [0,7813]	-0,195262 [0,4362]	***-0,216892 [0,0140]***	***-0,494156 [0,0064]***	-0,0395558 [0,8207]
RSILVER(-1)	0,0682765 [0,2506]	0,113657 [0,6348]	0,0390735 [0,6816]	***0,413603 [0,0077]***	0,0657266 [0,2129]	0,174835 [0,1060]	0,0446414 [0,6734]
RAGRICULTURE(-1)	-0,0689891 [0,7290]	-0,0643094 [0,9363]	-0,239857 [0,4545]	-0,461909 [0,3668]	0,0147238 [0,9336]	-0,144064 [0,6898]	-0,288156 [0,4192]
RFATSOILS(-1)	-0,06351 [0,4720]	-0,205648 [0,5641]	0,0087272 [0,9509]	0,181589 [0,4229]	-0,059417 [0,4483]	0,0917283 [0,5664]	0,229441 [0,1483]
RMETALS(-1)	-0,00653071 [0,9275]	***-0,532103 [0,0692]***	0,0752851 [0,5146]	-0,107921 [0,5580]	0,0267602 [0,6743]	0,114614 [0,3792]	-0,0768276 [0,5498]

Note: The values without parentheses are the coefficient values and in parentheses are the p-values. The values written with the red colour are the values that are statistically significant at 5% of significance.

For the analysis period of 2000 and 2007, movements among variables and effects seem to be more intuitive because we have oil returns being positively affected by its own lagged values and also being impacted but in a negative sense by lagged metals returns. Silver returns seem to be only positively explained by their own lagged returns, which are expected under market movements' expectations, but agriculture returns are now negatively affected by both the exchange rate and gold lagged returns similar to the results of Tyner (2008). Provided the increase in terms of international trade in the reference period these results were somehow expected. Fats oil returns during the considered period were now affected by other variables instead of its own returns as in the previous period, where we observe a negative impact of the exchange rate, oil returns and gold lagged returns over it. This result shows us the evidence of the results of Krugman (2008). Finally, metals seem to be only positively and significantly explained by lagged oil returns similar to the results of Akram (2008).

Table 15 - VECM, 2008-2015

VECM							
	RUS	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSOILS**	**RMETALS**
C	0,0023261 [0,4155]	-0,00189661 [0,8308]	0,0034167 [0,4151]	0,0046854 [0,5578]	0,00069174 [0,8239]	0,00054843 [0,9204]	-0,0002568 [0,9618]
RUS(-1)	-0,0038318 [0,9781]	0,0044436 [0,9918]	0,251711 [0,2211]	***0,738069*** ***[0,0618]***	0,0892195 [0,5580]	0,263752 [0,3273]	0,172342 [0,5120]
ROIL(-1)	***0,118813*** ***[0,0144]***	0,0218996 [0,8826]	-0,0058740 [0,9330]	0,160772 [0,2303]	-0,0236821 [0,6486]	-0,0106978 [0,9071]	-0,0525757 [0,5578]
RGOLD(-1)	0,159864 [0,2292]	-0,108603 [0,7922]	-0,176449 [0,3649]	-0,445507 [0,2316]	-0,152225 [0,2933]	-0,196397 [0,4415]	-0,354592 [0,1571]
RSILVER(-1)	-0,052313 [0,4737]	-0,0309485 [0,8916]	0,103993 [0,3324]	***0,398971*** ***[0,0535]***	-0,0157273 [0,8432]	-0,0921689 [0,5117]	0,0142024 [0,9175]
RAGRICULTURE(-1)	0,334635 [0,1580]	***-1,43389*** ***[0,0534]***	0,0217365 [0,9499]	-0,97401 [0,1426]	***-0,498317*** ***[0,0552]***	-0,415568 [0,3605]	-0,462227 [0,2986]
RFATSOILS(-1)	-0,14069 [0,2724]	0,47511 [0,2343]	0,128958 [0,4921]	0,480904 [0,1814]	***0,232553*** ***[0,0979]***	0,247482 [0,3155]	-0,172833 [0,4727]
RMETALS(-1)	-0,094923 [0,2097]	-0,197159 [0,4015]	-0,0348175 [0,7528]	***-0,363412*** ***[0,0878]***	-0,0461698 [0,5743]	-0,0853431 [0,5563]	0,072229 [0,6104]

Note: The values without parentheses are the coefficient values and in parentheses are the p-values. The values written with the red colour are the values that are statistically significant at 5% of significance.

For the last analysis period, which considers the "during and after" crisis period of 2008 until 2015, we are able to observe a loss of significance of other variables influence over fats oil, gold and metals returns. At least gold is seen as a safe haven commodity during crisis periods and the evidence of no significant impact of other variables over gold returns provides more evidence of this at least for the considered specific sub-period of analysis. In turn, now the exchange rate seems to have a positive and significant relationship with lagged oil returns, whereas there exists evidence of a negative and significant relationship between agriculture returns over oil returns. Thus, when agriculture returns increase, oil returns decrease for the crisis and in afterwards period. By opposition, agriculture returns are significantly and negatively explained by their own lagged returns being positively explained by lagged fats oil. Attending to the silver equation it is observed a positive and

statistically significant effect of the exchange rate and silver returns over it, whereas there is evidence for a negative impact of metals over silver returns.

The results of this VECM models come in accordance with the related study's conclusions in most of the cases like Tyner (2009), Nazlioglu and Soytas (2012), Byrne, Fazio and Fiess (2013). When does not come, it can be explained for other abnormal factors that can explain those different results. For example in the period from 2008 to 2015 the results of this study show that the RUS is influenced by the ROIL(-1). According to the related studies there is a relationship between the RUS and the ROIL and the other commodities in this study but that relationship is unidirectional. Just the RUS affects the values of the variables not the other variables affect the value of the RUS like in the studies of Coudert, Mignon and Penot (2005) and Sun, Lu, Yue and Li (2017). That happens because the FED doesn't take in to account the values of the commodities to stablish the value of the US dollar.

According to the most of the authors the value US dollar have impact on the value of the commodities. Akram (2008, p.18) "We find that fluctuations in commodity prices are mainly driven by shocks to the real interest rate and the real exchange rate." In the results of this study there were just a few times that, that impact was verified. In the period of 2000 to 2007 the RUS had impact on RAGRICULTURE and RFATSOILS.

Another relationship that was not verified on these results was the relationship between the RAGRICULTURE and the ROIL. This relationship is postulated by a few authors like Krugman (2008) and Gozgor and Kablamaci (2014).

4.5. Variance Decomposition

The following tables have the results of the Variance Decomposition of the Variables of the US Dollar Index, Crude Oil, Gold, Silver, Agriculture, Fats and Oils and Metals. In the column Period the 1 represents the 1st month, the 6 represents the 6th month or a Semester, the 12 is the 12th month or two semesters (one year), 18 is the 18th month or 3 semesters and the 24 is the 24th month or 4 semesters (two years).

Table 16 - Variance Decomposition of the RUS,1990-1999

Variance Decomposition of: RUS								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.025063	100.0000	0	0	0	0	0	0
6	0.026750	89.51643	3.698938	1.148471	0.408830	3.583630	0.787043	0.856662
12	0.027472	85.02247	3.548350	1.592850	0.409393	7.277896	1.330733	0.818309
18	0.028155	81.10080	3.378978	1.934199	0.410019	10.70836	1.686825	0.780822
24	0.028823	77.53677	3.225021	2.245722	0.411014	13.82457	2.010409	0.746504

Table 17 - Variance Decomposition of the RUS, 2000-2007

Variance Decomposition of: RUS								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.022255	100.0000	0	0	0	0	0	0
6	0.023319	93.07790	0.444486	0.904122	1.736491	1.242084	2.251103	0.343818
12	0.023509	91.68053	0.495288	1.216974	1.881522	1.916095	2.361459	0.448128
18	0.023683	90.43533	0.512013	1.509628	1.923241	2.573034	2.488763	0.557993
24	0.023856	89.22457	0.528501	1.793316	1.965785	3.212555	2.611928	0.663349

Table 18 - Variance Decomposition of the RUS, 2008-2015

Variance Decomposition of: RUS								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.026728	100.0000	0	0	0	0	0	0
6	0.038024	72.61814	6.573906	2.158406	10.12927	6.506618	0.283620	1.730042
12	0.047214	70.67653	6.919464	1.508566	10.28820	8.941516	0.520109	1.145613
18	0.054766	69.77258	7.107428	1.204074	10.44877	10.00222	0.595056	0.869868
24	0.061397	69.24229	7.212817	1.022678	10.54563	10.63073	0.638726	0.707125

Comparing tables 16, 17 and 18, each presenting the FEDV results but for distinct sub-periods we see that the results, of the returns of the exogenous variables impacts over exchange rate vary depending on the analysis period. Considering 1990-1999 interval, we observe that agriculture and oil shocks are able to explain about 13.82% and 3.23%, at the 2 years forecasting horizon, of the movements occurring in the variance of the exchange rate. However, the explanatory capacity of agriculture returns over the exchange rate decreases a lot in the following period (2000-2007) and oil returns lose their strength in favor of fats oil returns. The explanatory capacity of oil returns and agriculture increases again in the 2008-2015 period but now silver is able to explain more of the variance of the errors of the exchange rate than agriculture at least until 1 year (12 months) of forecasting horizon. This confirms the fact that in face of a crisis people turn their attention and wish to detain more commodities which do not lose much of their value in face of a crisis like silver and gold. To sum up, variance decomposition can tell the percentage of the fluctuation in a time series attributable to other variables at select time horizons. Looking at the 24 months forecasting horizon, in the period 2008-2015, for example, forecast errors for the exchange rate can be made up of 7.21% shocks to the oil returns, 10.55% shocks to the silver returns, 10.63%% to the agriculture returns, but only of 1.02%, 0.64% and 0.71% to shocks to the gold return, fats oil return and metals return, respectively. These values are not fixed and as exchange

develops across time the contribution of each of the variables mentioned on this metric can change and they do, both in terms of sub periods and in terms of forecasting horizon (for example, in the last period both gold and metals returns lose their explanatory capacity as the forecasting horizon increases).

Table 19 - Variance Decomposition of the ROIL, 1990-1999

Variance Decomposition of : ROIL								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.081866	1.377188	98.62281	0	0	0	0	0
6	0.096998	3.755780	77.35186	1.873782	0.474026	8.124941	3.838374	4.581233
12	0.100876	3.711445	71.53177	2.481059	0.479128	13.29142	4.222980	4.282200
18	0.104505	3.681518	66.65184	2.909516	0.474710	17.75837	4.531820	3.992222
24	0.108012	3.655522	62.39479	3.281788	0.471956	21.65526	4.801494	3.739187

Table 20 - Variance Decomposition of the ROIL, 2000-2007

Variance Decomposition of : ROIL								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.089918	1.394684	98.60532	0	0	0	0	0
6	0.097482	2.181332	87.89224	3.547572	1.078030	2.135091	0.603521	2.562215
12	0.097919	2.259065	87.14220	3.665750	1.129183	2.506920	0.700651	2.596231
18	0.098306	2.294034	86.47096	3.803710	1.157301	2.854012	0.782649	2.637336
24	0.098691	2.328534	85.81056	3.938598	1.186234	3.196033	0.862171	2.677871

Table 21 - Variance Decomposition of the ROIL, 2008-2015

Variance Decomposition of : ROIL								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.083237	22.29356	77.70644	0	0	0	0	0
6	0.158820	54.61913	27.98885	0.275881	7.309338	7.309338	1.303130	0.368995
12	0.217634	60.44316	18.50891	0.294098	9.031190	10.43131	1.062010	0.229319
18	0.263686	62.59064	15.03776	0.301009	9.635163	11.27455	0.981290	0.179588
24	0.302811	63.69933	13.24582	0.304773	9.946091	11.71046	0.939643	0.153885

In the interval 1990-1999, we observe that agriculture and fats and oils are able to explain about 21.66% and 4.28% at the 2 years forecasting horizon, of the movements occurring in the variance of the exchange rate. Looking at 1 year forecasting horizon in the same period the metals were the second variable with more capacity to explain the variance of the crude oil, with explanatory capacity of 4.28%. However, the explanatory capacity of agriculture returns over the crude oil decreases a lot in the following period (2000-2007) losing their strength to the crude oil return and gold. The results in the period (2008-2015) showed an exponential increase from 22.29% in one month of forecast to 63.70% at 2 years of forecast. These results can be explained by the financial crisis started in 2008 when these exchange rates were highly influenced by monetary policies leading these returns to have more impact on the variance of the crude oil, according to the results of the research of Sun, Lu, Yue and Li (2017).

In the same period the returns of the agriculture and silver had almost the same share of the returns of the crude oil with 11.71%, 9.95% and 13.25% respectively, showing a strong evidence that in this period crude oil had a big dependence of other returns. As oil is an important commodity for industrial production and energy production, in times of crisis the industrial production can decrease as happened in this time, so the variance of the crude oil can be more influenced by the returns for example of the agriculture where in times of crisis the consumption of agriculture commodities does not decrease as other commodities because people need to eat.

Table 22 - Variance Decomposition of the RGOLD, 1990-1999

Variance Decomposition of: RGOLD								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.028506	1.772953	3.363219	94.86383	0	0	0	0
6	0.033787	3.580829	3.108916	70.15517	1.500790	14.24123	4.797181	2.615888
12	0.036916	3.485133	2.608136	60.16719	1.356458	24.69262	5.482226	2.208233
18	0.039785	3.454708	2.248075	53.01935	1.227804	32.20720	5.937401	1.905465
24	0.042459	3.432690	1.975901	47.61685	1.130602	37.88623	6.280906	1.676825

Table 23 - Variance Decomposition of the RGOLD, 2000-2007

Variance Decomposition of: RGOLD								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.035796	17.11090	5.827999	77.06110	0	0	0	0
6	0.040306	21.54908	8.062485	62.62061	1.052304	4.302368	0.781221	1.631926
12	0.041921	20.50828	7.567487	59.35940	1.345861	7.590924	1.559141	2.068902
18	0.043452	19.55202	7.159872	56.71847	1.587540	10.29912	2.213358	2.469623
24	0.044931	18.72235	6.803562	54.41530	1.799507	12.65968	2.781960	2.817648

Table 24 - Variance Decomposition of the RGOLD, 2008-2015

Variance Decomposition of: RGOLD								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.039227	6.360733	0.005580	93.63369	0	0	0	0
6	0.046975	25.13583	1.535774	66.42687	3.552433	2.675097	0.594486	0.079514
12	0.050970	31.49212	2.402389	56.48371	4.725308	4.179844	0.629044	0.087580
18	0.054679	36.17165	3.083047	49.12171	5.538478	5.347067	0.651946	0.086101
24	0.058153	39.76521	3.609452	43.46532	6.162284	6.243007	0.670120	0.084609

In the period from 1990 to 1999 the return of agriculture was responsible for the biggest share of the variance of the gold. This responsibility was increasing in all the forecast periods till getting 37.89% in the second year of forecast. This result was so high that in the same period the importance of the returns of fats and oils and

the exchange rates together had less than half of the responsibly of the agriculture returns to explain the variance.

The next period from 2000 to 2007 had some changes where the importance of the returns of the agriculture decreased, even being the second highest, the returns of the exchange rate were the biggest ones in all the periods of the forecast. The capacity of explanation of the returns of the oil increased in this period in comparison with the previous period.

The last period from 2008 to 2015 as mention before started with the crisis so it is natural that the returns of the exchange rate were the main responsible for this variance because authors like Baur and Lucey (2010), say that there is a big correlation between the US Dollar index and the Gold. The same authors made this statement "Gold as safe Haven", so in time of economical uncertainty gold can be used as a safe asset. Like silver is also considered a safe asset it is natural that its returns strongly affect the variance of the gold.

Table 25 - Variance Decomposition of the RSILVER, 1990-1999

Variance Decomposition of: RSILVER								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.049900	0.392612	1.046941	19.60655	78.95390	0	0	0
6	0.055020	1.948270	1.781029	19.11598	66.05205	3.666498	2.907535	4.528640
12	0.056584	1.988607	1.694381	18.58163	62.48641	7.623737	3.332842	4.292394
18	0.058065	2.053276	1.609948	18.08465	59.36043	11.20812	3.605671	4.077902
24	0.059510	2.111845	1.533568	17.63641	56.53466	14.44718	3.852472	3.883865

Table 26 - Variance Decomposition of the RSILVER, 2000-2007

Variance Decomposition of: RSILVER								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.057089	6.535847	2.161603	43.89602	47.40653	0	0	0
6	0.062745	7.392144	3.559523	38.02403	46.10854	1.525522	0.940924	2.449318
12	0.063427	7.384816	3.588048	37.75183	45.23525	2.285380	1.124886	2.629790
18	0.064011	7.374362	3.551603	37.44382	44.50596	3.098803	1.303827	2.721628
24	0.064589	7.362784	3.517866	37.15328	43.79862	3.877410	1.476803	2.813235

Table 27 - Variance Decomposition of the RSILVER, 2008-2015

Variance Decomposition of: RSILVER								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.074880	17.76772	1.585492	52.79022	27.85657	0	0	0
6	0.114089	45.60141	3.963536	24.33864	18.00331	5.677261	1.778341	0.637498
12	0.140711	53.08991	5.049785	16.09248	15.75694	8.120499	1.426829	0.463561
18	0.163021	56.68560	5.704137	12.06979	14.52202	9.385262	1.269131	0.364062
24	0.182615	58.81640	6.094219	9.682976	13.79103	10.13474	1.175632	0.305002

In the period 1990 to 1999 the returns of gold and agriculture were the biggest responsible for the variance with 17.64% and 14.45% respectively. If we look at the agriculture at the same period at one month of forecast it did not had that importance with the fourth biggest return but with two years of forecast the impact of his return increased a lot. From 2000 to 2007 the returns of gold were again the most responsible for the variance with 37.15%. The second highest explanatory capacity is for returns from the exchange rate with 7.36%.

The following period from 2008 to 2015 showed that the returns of the exchange rate gained a huge importance in the variance with the value of 58.820%. These results were expected because of the period of crisis and the characteristics of the demand of silver. But was unexpected to observe the returns of the agriculture as the second more important, because if we look at the returns of gold at one month of forecast these were 52.79% but at two years of forecast the value was smaller than a fifth. A possible explanation for this decrease in the impact of the returns of the gold over the variance of the silver can be explained by a decrease of the impact of the crisis in the world economy.

Comparing this result of the last period of the silver with the results of the last period of the gold, the returns of the exchange rate had more importance in the variance decomposition in the silver than in the same period with gold. This statement was made because gold and silver can be classified as safe assets and as in this period there was a crisis, it can be the explanation for this result.

The results of the periods 1990-1999 and 2000-2007 support the statement of Radomski (2016) mentioned in this study on the part of the description of the data.

Table 28 - Variance Decomposition of the RAGRICULTURE, 1990-1999

Variance Decomposition of: RAGRICULTURE								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.017726	0.177753	1.036675	4.499545	5.472364	88.81366	0	0
6	0.029276	1.919278	0.646882	6.818973	3.055956	80.95884	6.495027	0.105042
12	0.038916	2.505531	0.372691	7.654219	1.922596	80.01460	7.456045	0.074313
18	0.046589	2.737504	0.265239	7.982281	1.471922	79.63316	7.848608	0.061286
24	0.053165	2.862031	0.207672	8.157704	1.230375	79.42924	8.058635	0.054346

Table 29 - Variance Decomposition of the RAGRICULTURE, 2000-2007

Variance Decomposition of: RAGRICULTURE								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.019747	0.590002	1.888917	13.70687	0.344750	83.46946	0	0
6	0.032815	4.294286	2.180815	19.57881	2.565282	61.51651	6.555837	3.308453
12	0.042378	5.263331	1.945703	20.18352	3.412706	55.63890	8.438891	5.116949
18	0.050136	5.680857	1.862614	20.45368	3.827862	53.10928	9.170593	5.895118
24	0.056844	5.914116	1.816434	20.60444	4.057133	51.70184	9.577057	6.328989

Table 30 - Variance Decomposition of the RAGRICULTURE, 2008-2015

Variance Decomposition of: RAGRICULTURE								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.029149	23.88965	12.59198	1.729014	4.190943	57.59841	0	0
6	0.054815	54.08249	7.534237	0.789505	10.09869	24.68022	2.616030	0.198829
12	0.072857	59.63255	7.650196	0.602896	10.46331	19.67920	1.828613	0.143233
18	0.087274	61.91870	7.640619	0.515726	10.60464	17.67900	1.519057	0.122259
24	0.099628	63.14198	7.636830	0.469394	10.67826	16.60880	1.353878	0.110859

In the first period from 1990-1999 the variance of the agriculture was affected in 8.16% by the returns of gold and 8.06% by the returns of fats and oils. The responsibility of the returns of the other commodities were smaller than 1.5% and the responsibility of the return of the exchange rate was smaller than 3%. Observing the

returns of silver at one month of forecast this one had the biggest share of the variance but were decreasing till reaching 1.23% at 2 years of forecast.

The next period, 2000 to 2007, main responsible for the variance of the returns were the same with 20.60% and 9.58% respectively. But in this period the behaviour of the returns of the exchange rate on the variance come in accordance with Maia (2003) and Tyner (2009).

In the last period, from 2008 to 2015, the returns of the exchange rate were the most responsible exogenous variable with 63.14% share of the variance decomposition giving emphasis to the study of the author mentioned in the paragraph above. The returns of silver explained 10.68% of the variance at 2 years of forecast. This weight in the variance was increasing with the increase in time of the forecasting periods. Looking at one month of forecast the returns of crude oil after the returns of the exchange rate were the returns with more impact in the variance. It was expected more impact of the returns of the crude oil on the variance because the crude oil is one of the main costs in the production of the agriculture commodities.

Table 31 - Variance Decomposition of the RFATSOILS, 1990-1999

Variance Decomposition of: RFATSANDOILS								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.034374	0.878856	0.891500	3.525934	0.001911	28.31218	66.38962	0
6	0.038254	1.278833	2.180823	3.922604	0.991070	28.51232	62.40851	0.705839
12	0.040117	1.432996	1.984379	4.382400	0.949018	33.03991	57.56196	0.649332
18	0.041895	1.585023	1.820982	4.744233	0.906265	36.83625	53.50931	0.597937
24	0.043599	1.714525	1.682684	5.050444	0.869834	40.05024	50.07778	0.554498

Table 32 - Variance Decomposition of the RFATSOILS, 2000-2007

Variance Decomposition of: RFATSANDOILS								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.040339	1.266319	0.303077	6.366746	0.277309	47.75772	44.02883	0
6	0.075599	4.415107	2.878342	16.05919	3.338144	47.67530	20.97813	4.655791
12	0.099780	5.337080	2.356673	18.25007	3.943640	47.32264	16.79426	5.995643
18	0.119109	5.750132	2.148507	19.11108	4.220099	47.15778	15.06434	6.548063
24	0.135711	5.975593	2.035028	19.57528	4.367055	47.06931	14.13092	6.846809

Table 33 - Variance Decomposition of the RFATSOILS, 2008-2015

Variance Decomposition of: RFATSANDOILS								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.051436	16.70531	16.84589	0.537687	2.373102	47.21734	16.32067	0
6	0.085385	48.13863	9.763516	1.183981	8.107186	22.85934	9.673275	0.274067
12	0.108255	55.16949	9.071808	0.889727	9.156337	19.17788	6.337974	0.196784
18	0.127126	58.46843	8.670648	0.731549	9.644428	17.50389	4.817738	0.163324
24	0.143543	60.34647	8.445065	0.642063	9.919597	16.54968	3.953234	0.143895

In the period from 1990 to 1999 at 2 years of forecast, the returns of the agriculture affected 40.50% and then the gold with 5.05% the variance of the fats and oils. The big share of the returns of agriculture in the variance of fats and oils can be explained for the big dependence that both have. Both are produced by farmers so if there is an opportunity of substitution by a farmer from agriculture commodity to the production of fats and oils or vice versa because of the values of this ones in the commodity markets they are going to do it, to take the maximum utility possible from their farm.

In the next period from 2000 to 2007 the main responsible for the variance were the same returns: agriculture responsible for 47.07% and gold responsible for 19.57%. Again, the returns of the agriculture were the main drivers of the variance. This can be explained because of the same reason on the paragraph below and there was a development in engines of cars and machines to increase the utility of the biodiesels, which might have caused an increase on the demand over fats and oils.

Finally, in the last period the most relevant return was from the exchange responsible for 60.35% and the returns of the agriculture with 16.55%. The results of the returns of the exchange rate and the returns of the agriculture in the variance come in accordance with the results of this one in the variance of the crude oil, proving a possible relationship between the crude oil and fats and oils.

Table 34 - Variance Decomposition of the RMETALS, 1990-1999

Variance Decomposition of: RMETALS								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.036357	0.001381	7.365968	2.005575	0.465210	4.340202	0.099108	85.72256
6	0.040526	0.721455	7.546674	4.910093	3.488048	5.867382	1.004667	76.46168
12	0.040778	0.754835	7.466450	4.973240	3.464657	6.712788	1.092217	75.53581
18	0.041017	0.784451	7.379869	5.015861	3.429719	7.550420	1.180737	74.65894
24	0.041255	0.813051	7.295242	5.058676	3.395258	8.368811	1.267805	73.80116

Table 35 - Variance Decomposition of the RMETALS, 2000-2007

Variance Decomposition of: RMETALS								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.039807	6.039477	9.461283	14.72991	5.156048	0.010466	0.131458	64.47136
6	0.051593	11.20440	9.176192	13.44534	5.265162	13.70066	5.352794	41.85545
12	0.060491	10.00650	7.193415	15.65553	5.173788	22.54334	6.796332	32.63109
18	0.068264	9.306475	6.002159	16.82691	5.107077	27.75024	7.699021	27.30812
24	0.075240	8.851146	5.233413	17.58818	5.063303	31.11379	8.282950	23.86722

Table 36 - Variance Decomposition of the RMETALS, 2008-2015

Variance Decomposition of: RMETALS								
Period	**Standard Error**	**RUS**	**ROIL**	**RGOLD**	**RSILVER**	**RAGRICULTURE**	**RFATSANDOILS**	**RMETALS**
1	0.050291	19.02094	23.13334	1.139257	8.288885	3.088860	0.050918	45.27780
6	0.108893	55.70892	12.66725	0.579415	8.011306	7.931090	3.513480	11.58855
12	0.146971	60.79191	10.42389	0.457817	9.293096	10.35657	2.268016	6.408703
18	0.177243	62.78825	9.549410	0.412818	9.803943	11.20561	1.810172	4.429799
24	0.203069	63.83383	9.090766	0.389832	10.07010	11.65166	1.571659	3.392161

Again, the returns of agriculture were the most responsible for the variance in the first (1990-1999) and second period (2000-2007) at 2 years of forecast. But in the second period the returns of agriculture had increased a lot the share in the variance passing from the value observed in the first period from 8.37% to 31.11% in the second period. It is curious because in the second period at one month of forecast the impact of returns of agriculture were the smallest ones in the variance and at two years of forecast this one had the biggest value. The returns of the gold were the second ones with more impact on the variance, in the second period.

In the last period from 2008 to 2015 the returns of the exchange rate assumed again the main role in the impact of the variance with the value of 63.83%. This result comes in accordance with Akram (2008) where metal values tend to display overshooting behaviour in response to interest rate changes.

5. Discussion

From the empirical results in this study, there was found some interesting results, even sometimes different with what was imagined before running the econometrical tests, but one possible explanation for this can be the periods chosen. This was also the main motivation to separate the analysis into different time periods: to see if results would change depending on the period under analysis, which revealed to be true. In this discussion section we will provide answers to the research questions that were the basis of this research, with the support of the empirical results which were previously presented.

5.1. Does the nexus between oil prices, exchange rate and commodity prices, differs due to the type of commodity analysed?

To study this question in the first place it is necessary to observe if there are any signs of correlation between the US Dollar and the Crude Oil. The Johansen test seem to be the most appropriate choice to test this correlation. The results of this test are presented in the tables 7, 8, 9, 10, 11 and 12. The results proved that there is a cointegration between these variables. In the second place it is required to study the relationship between the US Dollar and the Crude oil or in another words the capacity that each of these variables have to explain the other one. According to the tables 13, 14, and 15 this relationship was just verified in one period from 2008 to 2015 with a value statistically significant with a unilateral relationship where the value of the US Dollar is affected positively by the increase of the crude value. These results come in disagreement with the results from other authors like Novotny (2012), Coudert, Mignon and Penot (2005) and Sun, Lu, Yue and Li (2017). These different results can be explained from the performance of economic activity of the United States of America, where in 2014 it showed some signs of economic recovery such as decreasing of the unemployment, an increase in the house market, and by the decrease of the interest rates by the ECB and the Central Bank of Japan, making investors to shift from this currencies to US Dollar (Kristopher, 2015). As the United States of America is the biggest crude oil consumer in the world, the positive signs of the economy can explain the increase of the crude oil in the same period as the increase of the US Dollar value.

So, the increase in oil prices might be related with the positive American economy performance. America as the greatest consumer of oil in the world thus has a positive impact over it. However, an economic American recovery might mean increases in the Chinese production which in turn is the second highest world oil consumer provided the economic correlation existent between the two countries. Thirdly, dollar prices may have been affected positively by the investors changing behaviour in terms of Exchange rates, which might have switched from euro to dollars.

According to the results presented in the tables 13, 14 and 15 this relationship was just observed in the period from 2000 to 2007, when the US Dollar and Crude Oil affected simultaneously the Fats and Oils. This result can be explained from the perspective of the microeconomic theory of substitute goods, where some oils included in this group (Fats and Oils) can be imperfect substitute goods of the crude oil. As such, the increase on the prices of crude oil would increase the demand for substitute oils incorporated in the commodity group fat and oils, increasing his value according again with Krugman (2008). So, is the only time where this hypothesis is not rejected. Thus, we may infer from here that in economic expansion periods the different effect

of exchange rates and oil prices over different commodity types is more evident, reinforcing the need to account for different periods of analysis when considering the analysis of this type of relationships.

To the all other commodities this hypothesis is rejected. There was not found relationships between the US Dollar and Crude oil affecting simultaneously the values of the other commodities in any other period. There was found some negative impact the US Dollar in Agriculture in the period 2000 to 2007 and some positive impact in Silver in the period 2008 to 2015. The Crude oil had some positive impact in the Metals in the period of 2000 to 2007 and on the US Dollar as mention before in the period 2008 to 2015. As such, the answer to the first research question here explored is clearly yes, as we should also add the additional statement that it depends on the period under analysis.

5.2. Why the effect of oil and US Dollar should differ because of the different type of commodities

The reason why the effect of the US dollar and Crude oil should differ according to which commodity, is related with the unpredictably of the commodity markets. In each different period the behaviour of commodities differs between themselves, making it impossible to find long run patterns between them. These behaviours can be explained by some economic crisis, created by political reasons, natural disasters, financial crisis, or a thousand different reasons, causing shocks in supply or demand in the commodities that can affect their values and the US Dollar index. In most of the cases this abnormal events make the values of this variables to have a positive or negative trend, but in the long run this effect tends to vanish by the auto correction power of the market. So, in this study it is also studied this behaviour applying long run period analysis, to try to understand how can the behaviour of the commodities change in different time periods.

As the results from the question were rejected, it cannot be assumed as a rule that some commodities can be affected by the US Dollar and Crude Oil relationship. Furthermore, it seems to happen occasionally as the results of the tests of this research proved, and it was not found sustainable evidences to ground this relationship.

Gold and Silver can be classified as safe assets like as German Bonds for example. In times of crisis the demand for these ones tend to increase, because most of the people prefer to allocate their money in an asset with less risk of default. These phenomena were especially observed in the period after crisis 2008 to 2011 where the two commodities reached record values. So the behaviour of these commodities in this period was completely different of the behaviour of Crude oil, Agriculture, Metals and minerals, fats and oils. For example, in 2008 there was a big decrease of the US Dollar index. In reaction to that decrease the value of all the commodities in this study increased sharply, but was just observed a trend in the long run with respect to Gold and Silver, while in others the sharp rising vanished in a small period. This was the reaction of these commodities to this period of crisis, but if we look for example in the period of the Asian crisis, Gold values decreased as the values of the other commodities in this study excluding Silver where the value of this one increased. In this crisis the values of the US Dollar increased, because of the same reason of 2014 where the central bank of Japan, Malaysia, South Korea and Thailand decreased their currencies making the investors look at the US Dollar as a safe spot, which can justify the decline of the values of the commodities observed in the period.

Metals can be associated with macroeconomic variables like for example the industrial production in China as was proved in the research of Chen (2015). So, when the industrial production in China increases, the demand for metals increases and the value of this one too. In China, as the second biggest crude oil consumer, and like the crude oil is an important commodity to the industrial production, it was expected some significant statistic value to support the impact of crude oil in the metals.

The Agriculture commodities should differ for example from the Metal and Minerals behaviour, because the Metals and Minerals are more associated with the industrial production as mentioned in the paragraph above. In the case of the Agriculture commodities a comprehensive study by Deutsche Bank (2011) shows that rising prices for agricultural commodities are mainly caused by the fact that supply cannot keep pace with increasing demand. So, the key drivers include global population growth, rising incomes, changing diets in developing and threshold economies, and bio-fuel production. At the same time, water shortages, extreme weather, climate change, poor infrastructures, unjust land distribution and other factors are restricting supplies of agricultural products. International trade restrictions and subventions at national levels further aggravate the situation. As the bio-fuel production is one of the main drivers of the agriculture commodities and as the Crude oil is one of the main drivers of the bio-fuel production, it was expected similar results in this study, but these were not found.

Finally, the Fats and Oils commodities can have some similarities with the Agriculture commodities as these can be used in the people's diets, but the fats and oils can be used as an imperfect substitute good of the Crude oil. Provided this, it was expected more strong evidence in this study between these two commodities also, which was only verified in specific time periods and for the reasons already explored above.

6. Conclusion

The main objective of this research was to see how the interaction between the US Dollar index and the different commodities interact between them in the different periods, adding to this relationship analysis different types of commodities which in the literature were found to interact with both.

The first conclusion found on this research was related with the fact that no matter what is proved by some previous studies, the relationships between the variables studied can be different according to the period where the analysis is performed. Each period has their own particularities, where there are issues such as the weather for example that the human being cannot control. So, just this factor can affect for example the agriculture production leading to a negative shock in the supply increasing the prices of this agriculture commodity. The weather can affect too for example the production of renewable energy, if there is less wind or less sunlight, leaving the country that is dependent on this sources of energy, to find alternative sources such as Crude Oil, Natural Gas or Coal for example, increasing the demand for these commodities, that as a consequence is going to change the value of this one.

As was mentioned in the discussion, the two questions that this research aimed to answer were not completely proved by the empirical results. According to the results here observed it cannot be assumed a dual relationship US Dollar index/Crude Oil as a guideline of the values of the other commodities. The impact of the Crude Oil on the impact of the other commodities were not a rule, but instead was only observed sometimes. For example, in the results of the VECM, Fats and Oils proved to have more impact on more commodities in most of the periods than the Crude Oil, so with this result we do not show strong evidence of the US Dollar/Crude Oil relationship as a guideline of the values of other commodities.

There were some signs of Overshooting in the VECM and FEDV results run by this study especially in the period from 2008 to 2015. The values of most of the commodities used showed some signs of Overshooting by the decrease of the value of US Dollar Index impact. This means that the proportionality of decrease in the value of the US Dollar Index was not verified in the increase of the values of the commodities as Crude oil, Gold, Silver, Agriculture, Fats and Oils, Metals and Minerals. The most evident case of this Overshooting was observed by the commodity Crude oil that can be observed in figure 1, and the results attained through the FEDV proved similar to the findings of Frankel (2006). These phenomena can be observed because this commodity can be stored without losing substantially its quality over time, and with a decrease in the US Dollar index caused by a scenario of crisis can lead to an increase for the demand of this commodities. This, because they become cheaper and as they can be stored in the period after crisis, the markets tend to come to the steady state. Thus, with the decrease of the value of the US Dollar, it becomes cheaper to get this commodity, which can be one of the main reasons to justify the increase of the demand observed. Another reason can be related with the will of the countries to fill their needs faster in periods of crisis, because the crisis can lead some countries to bankrupt, which can thus affect the supply of some commodities. Another reason can be justified by the speculation factor. The decrease of the value of the US Dollar index can lead the investors to look at other assets with bigger returns but with more volatility like crude oil, or can lead the investor to want to allocate his money on safe assets like Silver or Gold.

As the Overshoot behaviour was mainly observed in the period of crisis, the results come in accordance with Sevensson (2005), where he defends that the central banks shouldn’t pay attention to values of the flexible

prices to set the inflation targets, but to the sticky prices. Looking at this period of crisis, most of the currencies lost their values, and the commodity values increased significantly. If the inflation targets were based on the flexible prices it would be a catastrophe in this period because the inflation in the majority of the developed and undeveloped economies would face a sharp rising that could lead to a serious shock in demand, and this crisis could even had bigger consequences to the real economy.

Finally, the main conclusion taken from the review of the literature presented here and empirical results, is that it is not possible to predict any kind of long trend of any of these variables in the future, because even if it was proven some relationships happening sometimes in the empirical results, these results are not one hundred percent responsible for the justification of real values verified in practice of these variables. In any econometrical model, there is always presented the error that cannot be explained by the model, so no matter how good is the model, there will be always thousands of other factors capable of explaining variable movements. These might even be the cause to justify the relationships between the variables here present, which as observed differ according to periods and circumstances. This research showed that there can be a relationship sometimes, but it cannot be assumed as a rule. Also other previous authors found opposite relationships, and they do not always agree with the results of one another. Even so, this work provided a strong contribution to the literature by analysing these relationships considering different time periods.

Despite the limitations already identified during the presented analysis, this work could be further extended in the future by considering different variables specifications and by adding other kind of commodities, which the previous authors identify as having their price affected by the exchange rate/oil prices nexus. It would also be interesting to analyse these results with a different frequency, like using daily data which could drive us to different conclusions provided markets act on a daily basis when defining commodity closing prices. Another possible avenue would be to include other countries into the analysis, like data applied for the Chinese market, to see if the country specific characteristics, and different macroeconomic variables would change the results with respect to the nexus.

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Appendix

The glossary of terms

- **Bretton Woods:** is the landmark system for monetary and exchange rate management established in 1944. It was developed at the United Nations Monetary and Financial Conference held in Bretton Woods, New Hampshire, from July 1 to July 22, 1944. Under the agreement, currencies were pegged to the price of gold, and the U.S. dollar was seen as a reserve currency linked to the price of gold.
- **Consumer Price Index:** is a measure that examines the weighted average of prices of a basket of consumer goods and services, such as transportation, food and medical care. It is calculated by taking price changes for each item in the predetermined basket of goods and averaging them. Changes in the CPI are used to assess price changes associated with the cost of living; the CPI is one of the most frequently used statistics for identifying periods of inflation or deflation.
- **Currency:** is a generally accepted form of money, including coins and paper notes, which is issued by a government and circulated within an economy. Used as a medium of exchange for goods and services, currency is the basis for trade.
- **Deficit:** is the amount by which a resource falls short of a mark, most often used to describe a difference between cash inflows and outflows. Deficit is the opposite of surplus and is synonymous with shortfall or loss.
- **Elastic demand:** refers to how sensitive the demand for a good is to changes in other economic variables, such as the prices and consumer income. Demand elasticity is calculated by taking the percent change in quantity of a good demanded and dividing it by a percent change in another economic variable. A higher demand elasticity for a particular economic variable means that consumers are more responsive to changes in this variable, such as price or income.
- **Emerging markets:** An emerging market economy is a nation's economy that is progressing toward becoming advanced, as shown by some liquidity in local debt and equity markets and the existence of some form of market exchange and regulatory body. Emerging markets are not as advanced as developed countries but maintain economies and infrastructures that are more advanced than frontier market countries.
- **Endogenous variable:** is a classification of a variable generated by a statistical model that is explained by the relationships between functions within the model. For example, the equilibrium price of a good in a supply and demand model is endogenous because it is set by a producer in response to consumer demand. It is the opposite of an exogenous variable.
- **Exogenous variables:** are considered independent. This means one variable within the formula does not dictate, or directly correlate, to a change in the other. Exogenous variables have no direct or formulaic relationship, such as personal income and color preference, rainfall and gas prices, or education obtained and favorite flower.
- **Fiscal policy:** is the government spending policies that influence macroeconomic conditions. Through fiscal policy, regulators attempt to improve unemployment rates, control inflation, stabilize business cycles and influence interest rates in an effort to control the economy.

- **Flexible exchange rate:** is a regime where the currency price is set by the forex market based on supply and demand compared with other currencies. This is in contrast to a fixed exchange rate, in which the government entirely or predominantly determines the rate. The currencies of most of the world's major economies were allowed to float freely following the collapse of the Bretton Woods system in 1971.
- **GDP deflator:** is an economic metric that accounts for inflation by converting output measured at current prices into constant-dollar GDP. This specific deflator shows how much a change in the base year's GDP relies upon changes in the price level. The GDP price deflator is also known as the "implicit price deflator."
- **Interest rate:** is the amount charged, expressed as a percentage of principal, by a lender to a borrower for the use of assets. Interest rates are typically noted on an annual basis, known as the annual percentage rate (APR).
- **Marshall Plan:** was a U.S.-sponsored program implemented following World War II to aid European countries that had been destroyed as a result of the war. It was laid out by U.S. Secretary of State George Marshall during an address at Harvard University in 1947. The plan was authorized by Congress as the European Recovery Program (ERP).
- **Monetary policy:** consists of the actions of a central bank, currency board or other regulatory committee that determine the size and rate of growth of the money supply, which in turn affects interest rates. Monetary policy is maintained through actions such as modifying the interest rate, buying or selling government bonds, and changing the amount of money banks are required to keep in the vault (bank reserves).
- **Overshooting:** is a phenomenon in economics used to explain why exchange rates are more volatile than would be expected. Some economists had argued that volatility was purely the result of speculators and inefficiencies in the foreign exchange market. However, the overshooting model argues that the foreign exchange rate will temporarily overreact to changes in monetary policy to compensate for sticky prices in the economy. Thus, there will be more volatility in the exchange rate due to overshooting and subsequent corrections that would otherwise be expected.
- **Producer Price Index:** is a family of indexes that measures the average change in selling prices received by domestic producers of goods and services over time. PPIs measure price change from the perspective of the seller and differs from other indexes, such as the Consumer Price Index, that measure price change from the purchaser's perspective. The PPI looks at three areas of production: industry-based, commodity-based and commodity-based final demand-intermediate demand.
- **Raw materials:** are materials or substances used in the primary production or manufacturing of goods. Raw materials are often referred to as commodities, which are bought and sold on commodities exchanges around the world. Raw materials are sold in what is called the factor market, because raw materials are factors of production along with labor and capital.
- **Sticky Prices:** is the resistance of a price (or set of prices) to change, despite changes in the broad economy that suggest a different price is optimal. "Sticky" is a general economics term that can apply

to any financial variable that is resistant to change. When applied to prices, it means that the prices charged for certain goods are reluctant to change despite changes in input cost or demand patterns.

- **Substitute goods:** in economics and consumer theory is a product or service that a consumer sees as the same or similar to another product. In the formal language of economics, X and Y are substitutes if the demand for X increases when the price of Y increases, or if there is a positive cross elasticity of demand.

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