The Impact of United States Monetary Policy in the Crude Oil futures market

By

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Abstract

This research examines the empirical impact the United States monetary policy, through the federal fund interest rate, has on the volatility in the crude oil price in the futures market. Prior research has shown how macroeconomic events and variables have impacted different financial markets within short and long – term movements. After testing and decomposing the variables, the two stationary time series were analyzed using a Vector Autoregressive Model (VAR). The empirical evidence shows, with statistical significance, a direct relationship when explaining crude oil prices as function of fed fund rates $_{(t-1)}$ and an indirect relationship when explained as a function of fed fund rates $_{(t-2)}$. These results partially address the literature review lacunas within the topic of the existing implication monetary policy has within the crude oil futures market.

Resumen

Esta investigación examina el impacto empírico que tiene la política monetaria de Estados Unidos, mediante la tasa de interés "fed fund", en la volatilidad del precio del crudo en el mercado de futuros. Investigaciones previas han mostrado como los eventos y variables macroeconómicas han tenido impacto en mercados financieros, causando movimientos a corto y largo plazo. Luego de realizar las pruebas y las descomposiciones, ambas series de tiempo fueron analizadas utilizando el modelo "Vector Autoregressive" (VAR). La evidencia empírica presenta, con un nivel estadísticamente significativo, una relación directa cuando se explican los precios del crudo en función de las tasas "fed fund" $_{(t-1)}$ y una relación indirecta cuando se explican los precios del crudo en función de las tasas "fed fund" $_{(t-2)}$. Estos resultados aportan parcialmente a las lagunas en la revisión de literatura sobre las implicaciones existentes entre la política monetaria en el mercado de futuros del crudo.

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List of Abreveations

ADF – Augmented Dickey Fuller test

CPI – Consumer Price Index

Crude – Crude oil futures price

Dif-log – Differential Logarithm

FED – Federal Reserve System Fed Funds – Federal Fund Interest Rate

H0 – Null Hypothesis

GARH - Generalized Autoregressive Conditional Heteroskedasticity

GDP – Gross Domestic Product

KPSS - Kwiatkowski-Phillips-Schmidt-Shin

Log – Logarithm

OLS – Ordinary Least Square

OPEC – Organization of Petroleum Exporting Countries

PR – Puerto Rico

T – Bills – Treasury Bills

T – Bonds – Treasury Bonds

T – Notes – Treasury Notes

US – United States

VAR – Vector Autoregression Model

WTI – Western Texas Intermediate

WTO – World Trade Organization

λ – Lambda Statistic

Chapter I - Introduction

1.1 Introduction

Crude oil is a vital component in the global economy and the energy market, the world consumption for this commodity is over 30 billion barrels per year. The role of this commodity in the global economy is crucial since countries, industries, and individuals are directly impacted with its demand and supply. The debate within the market of crude oil has opened discussions on the effects the commodity and its impact in global events, such as wars, recessions, and elections.

Oil prices have played a central role in the economic history within the last decade. In terms of value, oil accounts for a significant portion of commodities traded in the principal exchanges in the United States and the world. According to the World Trade Organization (WTO), the top three oil producing countries, as of 2008, are Saudi Arabia, Russia, and the United States. Oil consumption is indispensable for industrialized countries; United States, China, and Japan are accountable for the largest consumption, averaging 41.5 barrels/year per capita.

A rise in oil prices therefore has a far more pronounced effect on the industrialized countries/economies. Oil can be a very important inflation hedge because it directly impacts the general price level hence the consumption factor makes oil an essential commodity in the markets. Financial data typically show the spread and clustering of the volatility of the data.

Carefully following this market is indispensable to understand the role of crude oil in the economy. Such is why, economist, investors, bankers, scholars, policymakers, and the general public outlook this important commodity. A similar behavior is present when following the actions of the Federal Reserve Bank.

The Federal Reserve Act (ch. 6, 38 Stat. 251, enacted December 23, 1913, 12 U.S.C. ch.3) is the act of Congress that created the Federal Reserve System, the central banking system of the United States of America, which was signed into law by President Woodrow Wilson. The Federal Reserve System (FED) is the central bank of the United States. It was founded by Congress in 1913 to provide the nation with a safer, more flexible, and more stable monetary and financial system, among its main responsibility is conducting the nation's monetary policy by influencing money and credit conditions in the economy in pursuit of full employment and stable prices.

Over the years, its role in banking and the economy has expanded. In addition to conducting the nation's monetary policy it also maintains responsibility in supervising and regulating banking institutions to ensure the safety and soundness, maintaining the stability of the financial system, and providing financial services to financial institutions and governments.

A major component of the System is the Federal Open Market Committee (FOMC), which is composed by the members of the Board of Governors, the president of the Federal Reserve Bank of New York, and presidents of four other Federal Reserve Banks, who serve on a rotating basis. The FOMC oversees open market operations, which is the main tool used by the Federal Reserve to influence overall national monetary and credit conditions (monetary policy).

The FED, through the FOMC, implements monetary policy through its control over the federal fund rate (fed funds), a rate in which depositary institutions trade balances at the Federal Reserve. Its control is by influencing the demand for and supply for these balances through open market operations, reserve requirements, contractual clearing balances, and discount window lending.

The fed funds rate, as well as the discount rates and treasury instruments are used as proxies to monetary policy. The Fed Funds rate is probably the most significant economic indicator in the world. Particularly, due to the direct influence it receives from the FED. It plays a relevant role in the tightness or looseness of credit and liquidity in the financial system. It interplays in the control over events such as recessions and inflation.

In fundamental nature, crude oil and the United States monetary policy are critical in the development of industries, economies, and the world as a whole. Both are influenced by the demand and supply of the market, and are in the eye-watch of market movers, which see them as a direct influence in the economy. It is imperative to study the interaction and influence one has with the other.

1.2 Objective

It is conceivable that the risk in the derivatives market is not constant over time; volatility of the crude oil future can change as the market receives new information. Therefore the purpose of this research is to study the impact the United States monetary policy has in the crude oil futures market. This will provide an understanding on how the investor behavior is affected by the implementations of monetary policy through the fed fund rates and price fluctuations due to trading.

In an extended contribution to the domestic scenario, analyzing the effects the monetary policy linked to Puerto Rico, affecting the oil market in which it trades ought to open a discussion to alternative negotiations the Island can engage. It will provide a portion to an objective framework in which the Island should search for alternative options to oil negotiations in other markets.

Having empirical evidence of the outcomes the FOMC meetings will have in the futures for oil prices is indispensable, specifically the implications it has in Puerto Rico's domestic environment , to explain the volatility associated due to monetary policy changes. As previously mentioned, the market reacts to new information, and consumer behavior is mostly measured through price fluctuations within those markets.

The analysis will provide empirical evidence on how the movements in monetary policy might be responsible for the fluctuations in the futures markets for oil. This will be accomplished looking at the decision made by the FOMC regarding movements in the fed fund rates. Previous evidence has shown how the fluctuations in the futures market will be passed to the spot market [Silvapulle and Moosa (1999), Pyndic (2001), Shawke, Marathe, and Barrett (2002), Sundareson (2006) and. Ming (2008)]. It is important to notice this trend, since the market will usually follow the spot market. Documenting and analyzing these patterns will contribute to the debate that the prices in the oil market will react to changes in monetary policy.

1.3 Justification

An extended scope of literature review provides for gaps on the study on how the United States monetary policy impacts the futures markets. Most research has focused on how the crude oil market affects economies and their implications within country policy. Very few have researched how the crude oil market reacts to policy changes, and after an extensive review no previous research was found on how the United States monetary policy affects the crude oil futures market.

Understanding the futures pattern volatility provides a scope on how investors process information, and which information they consider important. It also addresses the relative importance to the US monetary policy carries, therefore can be suit as a leading indicator to crude oil derivative hedgers.

This topic is currently debated among the general public, which outreach those in the field of finance. It is notably a contemporary topic, where its research is pertinent to those that are affected by the fluctuations of the commodities traded in the futures markets. And further, those debating the trade off associated with monetary policy effects in the crude oil market.

1.4 Summary of following chapters

The subsequent chapters of this research will provide the theoretical framework of the topic, the data, statistics, and conclusions. The chapters are organized as follows. The second chapter presents the literature review, including macroeconomic research, futures trading, and oil price dynamics. This chapter provides the theory and previous research on topics that provide the foundations for this research. It also provides previous research on the area aligned with a description of used methodologies and tests to measure the intended relationships. The third chapter will outline the methodology and the statistics selected to conduct this research. The data used and detailed descriptions will also be included in this chapter. A discussion of the empirical results and the appropriate analysis are presented on the fourth chapter. Finally, the fifth chapter includes conclusions and recommendations that resulted from the research, as well as suggested areas for future research.

Chapter II: Literature Review

2.1 Introduction

This chapter reports the results of the review of information about the previous research within the topics of macroeconomics, futures trading, and oil prices. The development of different approaches to research the link dynamic between macroeconomics and financial derivatives are also presented. This literature review will provide the theoretical framework to understand the gaps in the topic that make this a valuable research for the finance field.

2.2 Macroeconomic research

Previous studies have shown how important the study of macroeconomic events can impact securities market. Studies like Simpson & Ramachander (2004), Horan, Peterson & Mahar (2004), and Barsky & Kilian (2004) studied how the crude oil and cash markets are affected with the information received in the events and news from the macroeconomic environment. A common approach on these researches is the link of variables to events which are measured against oil or cash prices. In contrast, the variables used are very broad, measuring different aspects of the macroeconomic environment, like consumer price index (CPI), gross domestic product (GDP), and 10 year Treasury bill yields.

Simpson & Ramchande (2003) studied the effects macroeconomic news had on the cash market and its financial derivatives. They focused their research on analyzing 23 major macroeconomic announcements by the United States agencies; and looked at the fluctuation in Treasury securities, such as T-Bills, T-Notes, and T- Bonds, at four different maturity dates. They found a direct link between the yields of United States (US) debt and the macroeconomic news published on key economic indicators such as non-farm payroll and United States Treasury budget. On the other hand, no effects were shown on new information surrounding inflation data. Within their results they found that the futures where co-integrated with the cash market and that macroeconomic news containing higher inflation and/or economic growth had a negative influence on cash and futures prices.

Within a similar perspective, Barsky and Kilian (2004) researched how oil prices shocks are closely related to macroeconomic performance. They analyzed how since the 1970's events in the macroeconomic environment affected the oil market, causing price shocks and their implications in events during that time horizon. They studied the events associated with subsequent oil increases, such as the Oil Embargo in 1973, the Irak-Iran outbreak in 1980, Irak invasion in 1990, and the OPEC meetings in 2001. They challenged the notion that at least the major oil price movements can be viewed as exogenous, or resulting from outside events, such as the U.S. macroeconomics. They addressed the scenario on events associated with the resulting recessions in industrialized countries in the world. Finally, they addressed how oil price shocks are essential in explaining stagflation, a period of increasing inflation and unemployment. None of the major price increases since the 1980's have been associated with stagflation.

Different indicators have been used to determine their effects on macroeconomic performance. For example, Dawson (2007) found that federal regulation is negatively related to aggregate economic performance in both the short and long run. Researches like this have been very common within the field of finance and economics, measuring macroeconomic performance in relationship to the stock market (Liang Chang, 2009), to interest rates (Guidolin and Timmermann, 2009), to oil prices (Barsky and Kilian, 2004), to export-import dynamics (Kandil, 2006), and regulations (Dawson, 2007). The empirical results have provided solid conclusions of the sensitive effects the U.S macroeconomic indicators have with the mentioned variables.

The use of macroeconomic indicators to determine their impact on different segments of the economy has provided valuable information to the field of finance. Using indicators such as Treasury yields (Simpson and Ramchande, 2003), and the stock market (Miskin and White, 2002), had provided evidence stating that financial instability is the key problem facing monetary policy makers. This makes an important contribution to the field, providing evidence that the responsibility of the FED is indispensable to provide optimal economic activity in the United States.

2.3 Futures trading

Understanding the behavior and the role of volatility is important in its own right. Price volatility drives the demand for hedging, whether it is done via financial instrument such as futures contracts. Given its relevance, consumers of the commodity are often skeptical of price fluctuations in the market. That is the reason most of them seek to hedge through a financial derivative to secure a specific price at a future date. For example, an oil future is a financial derivative that seeks to secure a price at a future date. The trading of crude oil, in the form of securities, consists in derivatives trading through commodity exchanges. Pindyc (2001), Brown and Curci (2002 & 2004), and Silvapulle and Moosa (1999) studied dynamics' in the futures market. These authors focused their research in relationships and implications of futures trading in the domestic and international markets. The common conclusions present empirical evidence that the futures market leads the spot market in trading dynamics for commodities, stocks indexes, and financial derivatives. Thus the spot market has a direct correlation to the futures market in price movements.

Previous scholars have studied the volatility the derivatives trading bring to the different markets, and the implications of their trading. Pindyc (2001) researched dynamics, using crude oil prices as an example, in the commodity futures markets and the consequent relationship between spot prices, futures prices, and petroleum inventory behavior. The interesting argument in the research is how equilibrium in this market affects and is affected due to price volatility in the futures market. He described how the supply and demand respond to an external shock, moving prices in the commodity market, and explaining the interconnection between futures prices, and the futures-spot spread.

Brown & Curci (2004 & 2002) researched how the level of futures contracts, used as a hedging activity, have affected the volatility for currency markets. Using Brazilian reals and the Mexican pesos as examples for their research; they empirically found the effects of futures trading within the market. What becomes interesting is their approach on how the trading activity, which reflects additional speculation-type activity, results in short-run increase volatility.

Using a micro approach to the spot-futures dynamic, Silvapulle & Moosa (1999), examine the lead—lag relationship between spot and futures crude oil prices using both linear and nonlinear causality testing. In their article, they concluded that future prices are drivers in the spot market; all information is reflected in the futures market which is lagged in the spot market. Focusing in the methodology used, the most appealing conclusion of the research is that the notion that financial and commodity market prices are generated from nonlinear processes remains controversial, therefore future studies should address each scenario and should be treated as such.

Providing a broader framework, Horan, Peterson, and Mahar (2004) researched the implied volatility prices of oil futures had surrounding OPEC meetings. Whereas this study shows how one of the main bodies in the oil market may influence the price of futures, the purpose of the content opened a debate about whether OPEC influences oil prices and provide any anomalies to the oil futures market. Their research focused on the volatility the oil futures have surrounding OPEC meetings and the potential investment strategies due to that volatility. It had an important conclusion on market volatility, where the results provide that the embedded volatility in option prices should move upward prior to scheduled information release and consequent consistent drops afterward. Conclusion in these studies has been able to provide how bodies controlling commodities make influence on trading behavior in the markets. This research complements those of Simpson & Ramachander (2004), Horan, Peterson & Mahar (2004), and Barsky & Kilian (2004).

2.4 Oil prices

Oil price dynamics in various time series have been characterized by high volatility, strong spikes, and strong upward drift, and were associated with underlying fundamentals of oil markets, global economies, and financial anomalies. Specifically pressure on oil prices resulting from firm crude oil supply and increasing world demand for crude oil have dramatically impacted the price of this leading commodity in the market.

Abosedra (2005), Crespo, Jumah, and Karbuz (2009), Moshiri and Foroutan (2006) researched models to study the behavior of oil prices. The importance these researches provide is the variables used to study oil prices in the macroeconomic environment. They all concluded on the complex dynamic of crude oil, as a commodity, which make them a difficult time series to analyze. Discrepancies arise in how efficient oil prices carry investor behavior (Abosedra, 2005) and sensitivity to new market information (Crespo, Jumah, and Karbuz, 2009). They also add the asymmetric cycles to oil price research, which they conclude that when taken into consideration provide a more efficient result in such volatile markets. They all agree in the economic instability crude oil price fluctuations bring to a countries economy. Particularly, Moshiri and Foroutan (2006), which concluded on specific seasonal decompositions that affect the crude oil derivatives market.

Empirical evidence has also been found when rises in commodity prices have been in response to weak dollar behaviors (Akram, 2008). His research presented that commodity prices tend to overshoot in response to interest rate changes that cause weakness in the dollar, when measuring the expected return on investments in the dollar as a currency. However, empirical evidence enlightened scholars the extent in which different commodity prices fuel each other, which lead to research the effect of the dollar, as a currency, in commodity price movements (Frankel, 2006).

Much researched was found on different models used to study the crude oil prices. For example, Abosedra (2005) researched the efficiency in the futures market for crude oil, she modeled using monthly observations of the West Texas Intermediate (WTI), a type of crude oil used as a benchmark in oil pricing and the underlying commodity of New York Mercantile Exchange's oil futures contracts. She concluded that univariate price forecast of crude oil, are both unbiased and (weakly) efficient when analyzing crude oil derivatives.

In further research, Cuarsema, Jumah, and Karbuz (2009) bring into consideration the topic of asymmetric cycles, the difference in the steepness in times of an oil bull market versus times of oil bear markets. Hence, it implies that in growing periods price increase is steeper than in decrease periods. They establish that commodity prices may be influenced by potentially cyclical monetary factors, given that most commodities are priced in dollars. They show that explicitly modeling asymmetric cycles on crude oil prices improves the forecast ability of univariate time series models of the oil price. Their findings present ample evidence that the nonlinear model is superior in terms of forecasting performance,

Moshiri and Foroutan (2006) results show that explicitly modeling asymmetric cycles on crude oil prices improve forecast ability to univariate time series of the commodity. They presented sample evidence that the nonlinear model is superior in terms of forecasting performance, when compared to its symmetric counterpart as well as a benchmark autoregressive model. They concluded that a nonlinear approach produces a substantial improvement in the accuracy of oil price forecast. Therefore, they suggest exploiting the asymmetric characteristics of the cyclical behavior of oil price data can an efficient method for understanding the dynamics of commodity prices.

2.5 Literature Review Lacuna

As shown in this literature review there is a lacuna to study how the United States monetary policy, through fed fund rates, affects the volatility in the futures market for crude oil. Previous studies mentioned in the prior paragraphs have the conceptual framework, which provide the foundations to make this study valuable to the field of finance. The lacuna in the literature review will be researched to provide additional evidence on the relationship among these variables.

Chapter III Methodology

3.1 Introduction

If macroeconomic announcements play a role in determining the prices of futures securities it stands to reason, that they will also impact the prices of those securities that are traded in their respective spot markets (Simpson & Ramachander, 2004). Using the federal fund rates (fed fund rates) as a proxy to monetary policy will be the best independent variable for this research. The strong dependence of futures prices on expectations plus the high trading activity of the financial derivative suggest that the crude oil futures market is a suitable variable to study the interaction between futures prices and the new information contained in the U.S. monetary policy announcements through fed fund rate fluctuations. The following sections portray the data, descriptive statistics, theoretical background, and methodology used in this research.

3.2 Theoretical Background

Many scholars and economists face challenges in selecting an appropriate technique to forecast dependent variables in a time series. The two main purposes of a time series analysis is to identify the nature of the observable fact represented by the sequence of observations and predict future values of the time series variable. Time series analysis, comprises methods for analyzing time series data in order to extract meaningful statistics and other characteristics of the data, is useful to observe how a given asset, security or economic variable changes over time. The collection of these observations provides patterns useful for the behavior of the given date. Since some behavior may not be noticed with a simple graph observation, patterns of the data may be unclear; hence empirical testing will be required for proper analysis.

Previous research have shown that if a model can be found which reasonably fits past observations it can be used to predict, under same conditions, values for them in the near future using time series analysis (Rao, 2005; Meade, 2000). Consequently, properly narrowing for a suitable method can lead to identify the best fitting time series model to forecast the dependent variable. Similar approaches haven been used when analyzing volatile time series, such as crude oil (Barsky and Kilian, 2004; Moshiri and Foroutan, 2006; Cuarsema, Jumah, and Karbuz, 2009; and Abosedra, 2005).

Forecasting a crude oil time series is challenging and complex due to the high level of volatility it contains, this makes the time series more unpredictable. Moshiri and Foroutan (2006) addressed this challenge in their work. Their tests indicated the crude oil time series follows a non-linear dynamic trend. Improving forecast models has been among the most difficult challenges faced by econometricians. There have been many efforts to develop models to explain changes in crude oil price and accurately forecast them in the spot and futures markets (Silvapulle and Moosa, 1999; Moshiri and Foroutan, 2006; Crespo, Jumah, and Karbuz, 2009; and Barrett, Marathe, and Shawky.2002). In contrast, simple regression models have been used to forecast in the futures markets for fed fund rates. Hamilton (2008) used a generalized autoregressive conditional heteroskedasticity (GARH) model to forecast the effect the fed fund futures rate had on treasury yields. His results provided consistency with prior researches within the same field of study when using a multivariate time series model. Hamilton’s evidence was enough to conclude that changes in fed fun futures are associated with large changes in Treasury yields (Hamilton, 2008).

After carefully researching the different methodologies scholars have employed in the previous researches of oil futures time series, the conclusion is the use of different statistics for similar scenarios (Rao, 2000). A common ground has been the constant improvement to forecast price shocks, yet none have found a single method suitable for all scenarios. Since no specific methodology was found to the best suitable for this type of analysis, a series of steps will help determine the time series model to be used. These steps include proper time series identification as univariate, one variable analyzed, or multivariate, more than one variable analyzed. It will be followed by a test to determine if the time series is stationary, that do not depend on time, or non-stationary, which will depend on time. Finally, depending on the result of the test, a specific model will be selected to analyze the data.

3.3 Data Description

The data required for the empirical analysis will be the daily fed fund interest rate and daily prices of crude oil (WTI) futures prices. All data is public information, which makes to easily available for the public and the use for this research. Fed fund rates are obtained from the Federal Reserve historical rate board of their web-site, the rates are changed when the FOMC makes a decision to change them, reaming unchanged otherwise. The closing prices, in which we consider that all the information is carried in these prices, for the futures will be those considered as the time series variables. The information will be gathered from the Bloomberg Financial Database, a financial information system used by the financial service industry.

The time series has been collected in a sequence from 09/01/2003 until 04/07/2009, using a 5 week interval[1]. This is a long enough period, which incorporates important events that have

1 For those days the markets are closed, we assume the prior day closing price.

impacted monetary policy, as well as the securities market, specifically the futures market. Most FOMC meetings are held during market trading hours. Therefore, we can observe any specific movements in the market which can possibly be associated to the meetings. To measure the impact of FOMC decisions, the federal funds key indicators of monetary policy, for the aforementioned period will be analyzed.

3.4 Methodology

As mentioned before, selecting an appropriate technique is challenging in these types of research. Hence, for the purpose of this paper a vector autoregression (VAR) model is the most flexible model used for the analysis for multivariate time series. This model has been commonly used for forecasting systems of interrelated time series and widely use in the applied econometrics field (Rao, 2005). It has proven to be especially useful for describing the dynamic behavior of economic and financial time series and forecasting using stationary observations (Diebold and Kilian, 2000; Askram, 2006). This model was used in Brown & Curci (2002-2004) when analyzing the relationship between volatility and futures trading activity. They used the augmented Dickey–Fuller test (ADF), a test for a unit root in a time series sample, in which the more negative the statistic is, the stronger the rejection of the hypothesis that there is a unit root at some level of confidence. If the ADF proves that the data is to be stationary, this will be the first model to fit the data for the research. It is imperative to statistically prove the time series are stationary.

Using the previous time series past data will help identify a suitable method that will fit to provide a proper forecast of the dependent variables in this research. Having two identified variables, the time series can be narrowed towards a multivariate model. Prior to estimating using VAR, the time series properties of the fed fund rates and the crude oil futures must be analyzed to ensure the suitability of the data for the use of the VAR model (Meade, 2000).

According to econometrics theory, among the advantages of VAR we find its simplicity in variable identification, since all variables are endogenous. Estimation is simple; Ordinary Least Square (OLS) method can be applied to each method. Finally, the forecasts obtained by this method are more efficient than those obtained from more complex simultaneous equations models of applied econometrics. On the other hand, some problems faced using the models are the useless of prior information; they are less used for policy analysis because of its emphasis on forecasting. It is also critical when using large sample sizing and can be complex to transform non-stationary series.

To analyze a multivariate model, it is indispensable to have two stationary time series. A time series is called to be stationary if its statistical properties do not depend on time, it has constant mean and variance over the time period of the series and whose statistical properties such as mean, variance, autocorrelation, etc. are all constant over time. An empirical analysis, unit root test, will diagnose if the time series is stationary or non-stationary and will provide a framework towards the selection of the time series model to test the variables (Diebold and Kilian 2000). However, time series data has to be identified as stationary or non-stationary in order for it to fit the VAR model. Most statistical forecasting methods are based on the assumption that the time series can be rendered approximately stationary through a mathematical transformation (Meade 2000). In contrast, a non-stationary time series, as a rule, are unpredictable and cannot be modeled or forecasted. When used in financial models generate unreliable and spurious results and leads to poor understanding and forecasting.

The solution to the problem is to transform the time series data so that it becomes stationary. In order to identify which model will be used; a test to determine if the data is stationary or non-stationary will be performed. A unit root test will help determine whether a time series variable is stationary using an autoregressive model, which will provide a more definitive answer on whether the data is stationary. This research will determine the unit root using the Dickey-Fuller test (ADF), which is an econometric test for whether a certain kind of time series data has an autoregressive unit root (Brown Curci, 2002, 2004; Maede, 2000). The ADF test was developed in 1979 and has been the most fitted option to test stationarity in a time series. It specifically addresses whether the null hypothesis of a unit root can be rejected. The test will provide enough evidence to determine if the data is stationary or non-stationary, so the proper model can be chosen. We will first test the Augmented Dickey-Fuller (ADF) at level and the AFD at 1st level, if both tests are rejected the time series is stationary (Maede, 2000). In contrast, if either of the tests does not reject the null hypothesis, a third test, Kwiatkowski-Phillips-Schmidt-Shin (KPSS) level, will help to conclude whether the time series is stationary (Maede, 2000).

The null hypothesis **(H_0)** states that the series is non-stationary. This will be measured using the comparison of the t-statistic and critical value. If the critical value is more negative than the t-statistic **(H_0)** will be rejected, hence the series is stationary. Otherwise, if the t-statistic is more negative than the critical value **(H_0)** is not rejected, therefore the time series is non-stationary. The augmented Dickey–Fuller (ADF) statistic, used in the test, is a negative number. The more negative it is, the stronger the rejection of the hypothesis that there is a unit roots at some level of confidence.

The test hypothesis for each unit root test is statically expressed as follow:

Unit root test	Null Hypothesis (H_0)	Alternative Hypothesis
Augmented Dickey–Fuller	$\gamma = 0$	$\gamma < 0$
Augmented Dickey–Fuller – 1^{st} level	$\gamma = 0$	$\gamma < 0$
KPPS	$\gamma = 0$	$\gamma < 0$

After the stationary tests have been performed and the t-statistic is accepted, the time series is said to be non-stationary. Thus having an inconsistent mean and variance over the time period of the series and whose statistical properties such as mean, variance, autocorrelation, etc. A time series must undergo a de-trending process in order to transform it from a non-stationary to a stationary time series plot

Decomposition of this data to leave a stationary data set for analysis is referred to as de-trending (Maede, 2000). An observed time series can be decomposed into three components: trend (long –term direction), seasonal (systematic, calendar related movements), and irregular (unsystematic, short-term fluctuations).

A trend can be defined as the “long term” movement in a time series without calendar related and irregular effects, as is a reflection of the underlying level. In the case of crude oil futures it can be the influence of wars, recessions, or policy implementations. A seasonal effect is a systematic and calendar related effect. These can include, trading days, OPEC meetings, or season effects (increase of heat during winter). Finally, irregular components of the series, is what remains after the seasonal and trend components of a time series haven been estimated and removed. These can be unsystematic and short-term movements. For example, high volatility for the market trading day, as a consequence of an extraordinary event in a domestic market (i.e. policy regulations for gas price in the United States. In order to find the unit root for the crude oil futures price, the time series must be decomposed its trend, seasonality, and irregular fluctuations.

The Hodrick-Prescott Filter is a mathematical tool used to separate the cyclical component of a time series from raw data. This method is commonly used in the econometrics field to decompose a non-stationary time series. It is used to obtain a smoothed non-linear representation of a time series, one that is more sensitive to long-term than to short-term fluctuations. As for the crude oil futures time series, due to the high level of fluctuation it is a good fit to decompose the time series data. The adjustment of the sensitivity of the trend to short-term fluctuations is achieved by modifying a multiplier λ. The following equation represents the Hodrick-Prescott Filter equation, which interpretation was detailed by Ahumada and Garegnani (1999).

$$\text{MIN} \sum_{t=1}^{T} (y_t - \tau_t)^2 + \lambda \sum_{t=2}^{T-1} [(\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1})]^2.$$

The series y_t is made up of a trend component, denoted by τ and a cyclical component, denoted by c such that $y_t = \tau_t + c_t$.

These components will be decomposed using a logarithm (log) function to the 10th base and will transform the data in a time series to make them providing consistency in mean, variance, and autocorrelation. The log is used to decompose the trend component of the time series, whereas the differential-logarithm (dif-log) is used to decompose the cyclical or seasonal component. These functions will eliminate the fluctuation and volatility from the time series, thus transforming them in a stationary series.

It can be useful to observe the slope coefficient of the trend line of the plots for both the log and dif-log time series. A low coefficient on the slope can be interpreted as stable plot of data in the line, which we can deduct, represents a stationary time series.

Finally, the VAR model analysis can be performed after having all the variables in a set of a stationary series or having de-trended from its original non-stationary time series. The most basic form of a VAR analysis treats all variables symmetrically without making reference to the issue of dependence versus independence. The information incorporated in a VAR analysis can be helpful in understanding the interrelationships among economic variables and in the formulation of a more structured economic model to measure a set of variables.

In case of two-variable scenario, we can let the time path of the (y_t) be affected by current and past realizations of the (z_t) sequence and let the time path of the (z_t) sequence be affected by current and past realizations of the (y_t) sequence.

$$y_t = b_{10} - b_{12}z_t + \gamma_{11}y_{t-1} + \gamma_{12}z_{t-1} + \epsilon_{yt}$$
$$z_t = b_{20} - b_{21}y_t + \gamma_{21}y_{t-1} + \gamma_{22}z_{t-1} + \epsilon_{zt}$$

It is assumed that first, both y_t and z_t are stationary; second, €$_{yt}$ and €$_{zi}$ are white-noise disturbances with standard deviations of °y and 0 z, respectively; and third, €$_{yt}$ and €$_{zt}$ are uncorrelated. Finally, the lags, the number of periods that a dependent variable in a regression model is "held back" in order to predict the dependent variable, need to be stated before the model is calculated. A reduction of the equations can be transformed to a system of equations more usable, which set the basis of interpretation of a calculation output. Using matrix algebra, we can write the system:

$$B = \begin{bmatrix} 1 & b_{12} \\ b_{21} & 1 \end{bmatrix}; \; x_t = \begin{bmatrix} y_t \\ z_t \end{bmatrix}; \; \Gamma_0 = \begin{bmatrix} b_{10} \\ b_{20} \end{bmatrix};$$

$$\Gamma_1 = \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix}; \text{ and } \epsilon_t = \begin{bmatrix} \epsilon_{yt} \\ \epsilon_{zt} \end{bmatrix}$$

For notational purposes, we can define a_{10} as element i of the vector A_0; a_{il} as the element in row i and column j of the matrix A_1; and $€_{it}$ as the element i of the vector $€_t$. Using this new notation, we can rewrite in the equivalent form of:

$$y_t = a_{10} + a_{11}y_{t-1} + a_{12}z_{t-1} + e_{1t}$$
$$z_t = a_{20} + a_{21}y_{t-1} + a_{22}z_{t-1} + e_{2t}$$

The VAR model, as expressed in the previous equation will provide, incorporating all assumptions, the mathematical model to forecast a two variable time series in respect to each other.

Further analysis of the VAR provide an output graphs of the impulse response function (IRF), which refers to the reaction of any dynamic system in response to some external change, traces out the response of a variable of interest to an exogenous shock. The impulse response describes the reaction of the system as a function of time, or possibly as a function of some other independent variable that parameterizes the dynamic behavior of the system. It is portrayed graphically, with horizon on the horizontal axis and response on the vertical axis.

The mean line of the time series will be between two lines, which explain the significance of the variable in response to the shock. When the parameter lines touch or come close to the x-axis, then the response to the shock are irrelevant in the fluctuation of the time series. Therefore, we can determine the impact of the shock in the variable by tracing those lines until they are tangent to the x-axis in the graphical output.

Chapter IV: Results and Analysis

4.1 Introduction

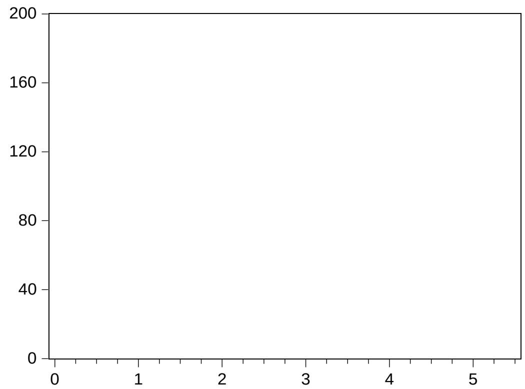
The following chapter explains the empirical results and analysis of the data using the statistics and methodology explained in chapter III. It has been divided into 4 sub-sections illustrating data statistical properties, stationary tests, and VAR model forecasting. All the data has been analyzed using E-Views 6 (student version) and Microsoft Excel 2007.

4.2 Plot series statistics

Tables 4.1 and 4.2 provide the general statistics for the fed fund rates and crude oil futures prices that explain the statistical properties of the respective time series. Figures 4.1 and 4.2 provide a visual representation of the time series plots, where the trend, cycles, and time series behavior can be visualized to better understand the behavior of the data.

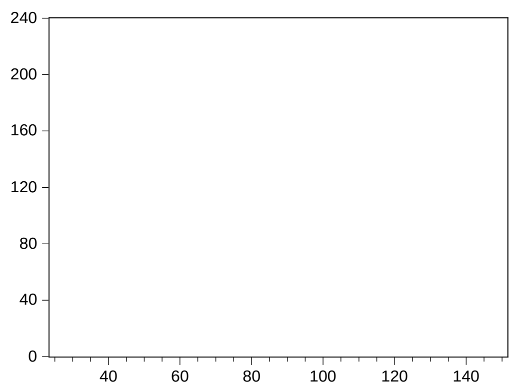
The mean fed fund rates in the period is 2.93% with a standard deviation of 1.80%; they do not vary in size nor duration, keeping steady pace at intervals, thus indicating a linear dynamic. The strongest variance within its own mean, indicating more volatility, occurs the period of the United States economic meltdown. The distribution seems to be normal, since it is not heavily skewed to either side. Table 4.1 resumes the statistics and provides the histogram for the data.

Table 4.1 - Fed Fund Rates Statistical Properties



Series: RATES	
Sample 10/01/2003 6/30/2009	
Observations 1440	
Mean	3.039625
Median	2.990000
Maximum	5.410000
Minimum	0.080000
Std. Dev.	1.745895
Skewness	-0.086755
Kurtosis	1.565288
Jarque-Bera	125.3102
Probability	0.000000

Table 4.2 - Crude Oil futures prices Statistical Properties



Series: PRICES	
Sample 10/01/2003 6/30/2009	
Observations 1440	
Mean	62.89390
Median	63.72500
Maximum	145.4500
Minimum	25.91000
Std. Dev.	25.18947
Skewness	0.771498
Kurtosis	3.795770
Jarque-Bera	180.8452
Probability	0.000000

The mean of the futures price for crude oil is \$62.89 with a standard deviation of \$25.19. Futures oil prices fluctuations vary in size and duration, thus indicating a dynamic non-linear structure may exist in the time series and suggest irregular patterns in the graph. These patterns will be tested to determine if the time series have a unit root. Major oil prices where experienced during the sampled observations. An intense spike was observed during 2007, when a notable weak dollar was trading in the currency markets. A heavy drop was observed in 2008, a strong contributor to this price decline was the drop in demand for oil in the US. Miles driven there in a month were down in March-May 2008 compared to 2007, with the 4% decline in May being the largest drop in history; according to the United States Department of Transportation.

Figure 4.1 - Fed fund rate time series plot

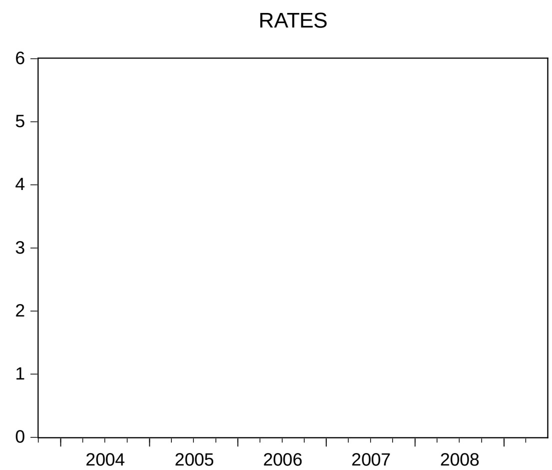
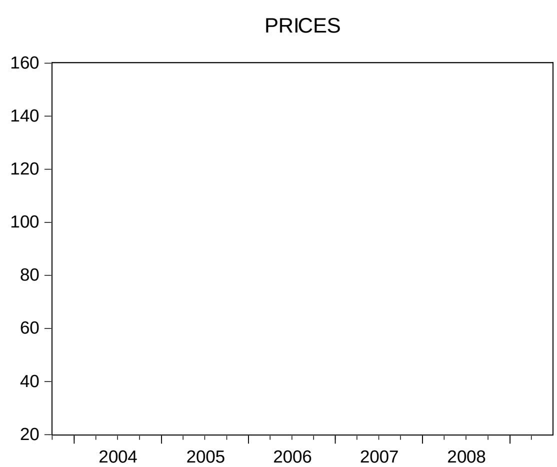


Figure 4.2 - Crude oil futures price time series plot



4.3 Stationary series tests

This section provides the test results to determine if the respective data series have a unit root. Using the statistics and following the methodology explained in sections 3.3 and 3.4, three tests will be performed to determine if a unit root exist in each variable. The hypothesis used the unit root test ADF at level, ADF at 1st level, and KPSS is that a unit root exists is the same for all three statistics. If the test statistic is less than (a larger negative) the critical value, then the null hypothesis of $\gamma = 0$ is rejected and no unit root is present.

The results of the tests will provide the conclusion to the time series unit root null hypothesis **(H_0)**, which are the following:

Table 4.3 - Fed Fund Time Series Unit Root Test[2]

Test	T-Statistic	Critical Value	H_0	Result
ADF – Level	**-0.13**	**-3.43**	**Rejected**	**Stationary**
ADF- 1st Level	**-19.17**	**-3.43**	**Not rejected**	**Non-Stationary**
KPSS	**1.15**	**0.74**	**Rejected**	**Stationary**

Table 4.4 - Futures Price Time Series Unit Root Test[3]

Test	T-Statistic	Critical Value	H_0	Result
ADF - Level	**-1.57**	**-3.43**	**Rejected**	**Stationary**
ADF- 1st Level	**-36.10**	**-3.43**	**Not-Rejected**	**Non-Stationary**
KPSS	**.137**	**.739**	**Rejected**	**Stationary**

[2] Appendix 1, 2, and 3 detail E-views test outputs

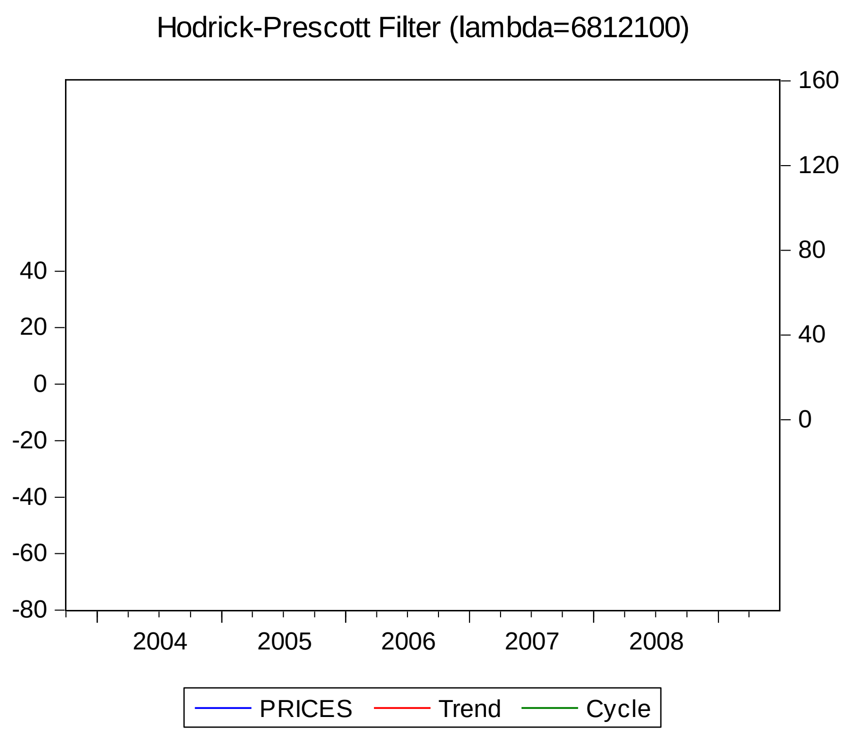
[3] Appendix 4, 5, and 6 detail E-views test outputs

In summary, there is enough evidence to conclude that the fed fund interest rate is stationary and the futures price for crude oil is non-stationary. A process of transforming is imperative to provide a suitable set of data for the use of the VAR forecasting model.

4.4 Non-Stationary time series decomposition into stationary time series

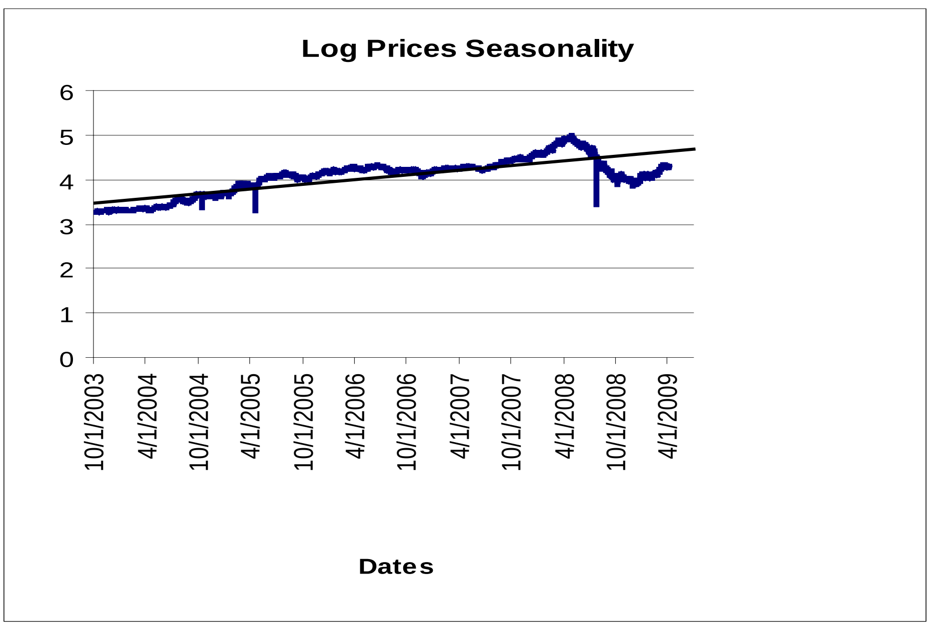
The crude oil futures price time series must be decomposed, as mentioned in section 3.3 to eliminate the volatility of the time series. Figure 4.3 provides the plot of the trend and seasonal decompositions; irregular fluctuations will not be taken into consideration due to the complexity of its volatility due to extraordinary events, as mentioned in section 2.4.

Figure 4.3 Hodrick-Prescott Filter plot



The trend component time series is the long term movement in a time series without calendar related and irregular effects. Figure 4.4 provides the plot to the crude oil futures price trend decomposition. As we observe in the graph, after taking the log of the data, the volatility has been reduced and the mean and variance seem to follow a consistent trend. It is mainly reflected through the underlying time series data. This is the result of influences such as economic changes, supply and demand of the commodity, and macroeconomic effect, like inflation. It is decomposed using the log prices seasonality data. Figure 4.3 provides the trend component decomposition, which is built with the time plot of the log prices of the time series (Brown and Curci, 2002, 2004; Ahumada and Garegnani, 1999). The equation of the tendency line for the trend component decomposition graph is: $y = 0.0006x - 18.177$; where the slope of the line is 0.0006, which indicates the elimination of volatility of the component.

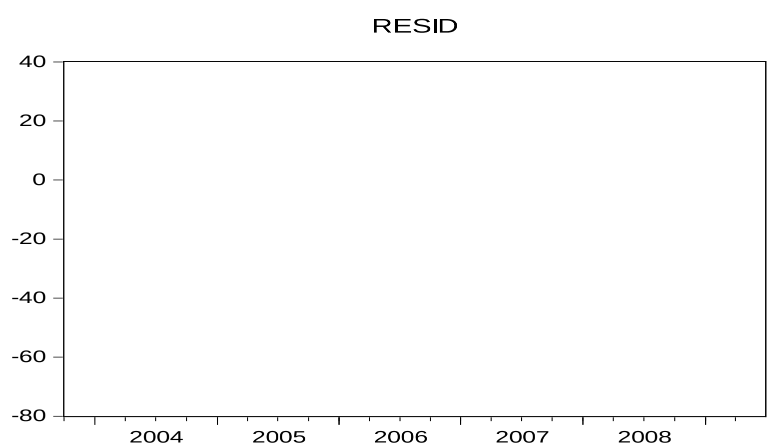
Figure 4.4
Crude Oil futures price trend decomposition plot



The seasonal or cycle component consists of effects that are reasonably stable with respect to timing, direction and magnitude. It arises from systematic, calendar related influences such as natural conditions, business procedures, and industry behaviors. It also includes calendar related cyclical effects that are not stable in their annual timing or are caused by variations in the calendar from year to year, such as trading days and moving effects in calendar days, like meetings of the OPEC. A cyclical component in a time series can be identified by regularly spaced peaks and troughs which have a consistent direction and approximately the same magnitude every year, relative to the trend. The effect of this component can be observed in various stages of the graph, specifically in 2008 with the sudden drop due to shortage of demand of the commodity.

The cycle decomposition is obtained with the log dif prices of the original time series values. Figure 4.5 shows the log dif plot of values, the graph illustrates how the noise and volatility effects have been removed Brown and Curci (2002, 2004) Ahumada and Garegnani (1999). The trend line equation for the cycle component decomposition is: y = -1E-06x + 0.0445.

Figure 4.5 Crude Oil futures price seasonality decomposition plot



There are three methods of determining if the time plot is stationary, two of them are by observations and the other one empirically. First, observe the behavior of the graph, second look at the slope coefficient on the tendency line equation, and finally test the unit root, where H_0 expresses whether the time series is stationary.

After decomposing the price seasonality time plot, we can observe a stationary behavior. It seems the variance and mean follow a constant behavior in the time series. Thus, a log differenced (dif log) plot is observed to have eliminated all noise, fluctuation and volatility to the time series. Secondly, the equation of the trend line of the plot is y = -1E-06x + 0.0445; the value of the slope coefficient is almost reaching 0, which indicates the existence of a horizontal line that crosses all the points in the graph. We can assume a stationary behavior using the coefficient value. Finally, Table 4.5 provides the results for the unit root test performed after decomposing the crude oil futures price series. As shown, we can conclude that the aforementioned time series has become stationary.

Table 4.5 - Unit root results of differenced log of crude oil futures price[4]

Test	T-Statistic	Critical Value	H_0	Result
ADF - Level	**-40.79**	**-3.43**	**Rejected**	**Stationary**
ADF- 1st Level	**-18.89**	**-3.43**	**Rejected**	**Stationary**
KPSS	**0.017**	**0.739**	**Rejected**	**Stationary**

[4] Appendix 7, 8, and 9 provided a detail E-views test output

After performing all three unit root tests, there is enough evidence to conclude that the crude oil time series dif-log is a stationary series, thus this will be the time series used in the VAR model as the crude oil futures price.

4.5 VAR Analysis

The obtained results where a calculation of the fed fund rates time series with the crude oil time series futures price using the dif log data, provided a stationary time series after decomposition (Brown and Curci, 2002, 2004). The VAR model (with E-Views 6 – Student Version) used to forecast and explain the relationships within the fed fund rates and crude oil futures price are summarized in Table 4.6.[5]

For the estimation, all assumptions have been satisfied, fed fund rates and crude oil futures price are stationary; second, $€_{prices_{12}}$ and $€_{crude\ oil\ futures_{12}}$ are white-noise disturbances with standard deviations of and 1.74 and 25.18, respectively; and finally, $€_{prices_{12}}$ and $€_{crude\ oil\ futures_{12}}$ are uncorrelated.

[5] VAR detailed output attached in Appendix 10

Table 4.6 – Vector Autoregression (VAR) estimates analysis output

	Rates	**Price**
Rates(t-1)	0.980418***	0.011994
	(0.02642)	(0.01007)
	[37.1054]	[1.19144]
Rates(t-2)	0.018011	-0.011997
	(0.02644)	(0.01007)
	[0.68133]	[-1.19122]
Prices(t-1)	0.060963	-0.566661***
	(0.06787)	(0.02586)
	[0.89825]	[-21.9149]
Prices(t-2)	-0.066896	-0.207097***
	(0.06792)	(0.02588)
	[-0.98487]	[-8.00271]
Notes: Standard errors in parentheses and t-statistics in brackets ***Significant at 1% level		

The results of the VAR analysis provided information regarding which variables are significant to each other within the analysis. Table 4.6 shows that certain variables have a statistical significance at one percent level. Notably, we can make the following interpretations of the results. In first instance, the fed fund rate market has a direct relationship within its own market, which represents a statistical significance in fed fund rates$_{(t-1)}$ but not in fed fund rates $_{(t-2).}$ For the crude oil market futures there is an indirect and significant relationship within its own market for both lags, crude oil futures prices$_{(t-1)}$ and crude oil futures prices$_{(t-2)}$. If each variable is expressed as a function of the other we can interpret a forecast of the movements of each variable in terms of the other.

The equation provided by VAR allows to forecast the crude oil future price as a function of movements in the fed fund rates market and movements within its own market (Brown and Curci, 2002, 2004; Brooks, 2008; and Crespo, Cuarsema, and Jumah, 2009).

Crude Oil Futures Price = 0.01199*Fed Fund Rates$_{(t-1)}$ - 0.01199*Fed Fund Rates$_{(t-2}$ - 0.56666*Crude Oil Futures Price$_{(t-1)}$ - 0.20709*Crude Oil Futures$_{(t-2)}$ + 0.00127

The coefficient variables are explained as follows. Fed fund rates $_{(t-1)}$ means a movement in the fed fund market the day before a movement in the crude oil futures market today. Fed fund rates $_{(t-2)}$ is defined as a movement in the fed fund market two days before a movement in the crude oil future market today. Crude oil futures prices$_{(t-1)}$ means a movement a day prior to a movement in the crude oil futures market today. And lastly, crude oil futures prices$_{(t-2)}$ is defined as a movement two days prior a movement in the crude oil futures market today.

Expressing movements of the fed fund rates as an independent variable, which is the purpose of this research, to forecast movements in the crude oil futures market, we obtain that a movement one day prior is directly proportional to a movement the futures today. Thus, a positive movement in fed fund rates$_{(t-1)}$ will provide a positive movement of crude oil in the futures market today. In contrast they are inversely proportional when explained with fed fund rates$_{(t-2)}$. This means, that a positive movement in fed fund rates$_{(t-2)}$ will move the crude oil futures market negative today. This analysis provides the best piece of statically information of this research of the impact of monetary policy, in terms of fed fund rates, in the crude oil futures market.

However, further analysis provides useful information on the behavior of these markets. Looking into the fed fund rate movement within itself, we can observe it has a direct relationship within its own market in fed fund rate $_{(t-1)}$ and fed fund rate $_{(t-2)}$. As a result, a positive movement in fed fund rates $_{(t-1)}$ and $_{(t-2)}$ will provide a positive movement in the fed fund rate today, being statistically significant at fed fund rates $_{(t-1)}$.

An examination of fed fund rates forecast as a function of movements in crude oil price futures yields useful information when prices are used as the independent variable. The following equation expresses fed fund rates as a function of crude oil futures prices and within its own market.

Fed Fund Rates = 0.98041*Fed Fund Rates$_{(t-1)}$ + 0.0180*Fed Fund Rates$_{(t-2)}$ + 0.06096*Crude Oil Futures Price$_{(t-1)}$ - 0.06689*Crude Oil Futures Price$_{(t-2)}$ + 0.00419

The information yield with this equation suggests that crude oil future prices$_{(t-1)}$ have a direct relationship with movement in fed fund rates. Contrary to the movements in crude oil future prices$_{(t-2)}$ in which an inverse movement exists within the fed fund rates today, thus the inverse relationship mirrors the inverse relationship when analyzing crude oil futures as a function of movements in the fed fund rate market.

Lastly, an inverse relationship exists when analyzing crude oil futures within its own market. An indirect and significant relationship exists for both crude oil futures $_{(t-1)}$ and $_{(t-2)}$ in respect to movements within its own market today. Notably, an opposite relationship occurs when analyzing the fed fund rates within its own market, but the model only shows statistical significance in rates$_{(t-1)}$.

These results provide consistent results as for those of Pyndic (2001) in which derivatives trading brings volatility to different markets, including interest rates, in this case. An interesting scenario is observed since both markets, when expressed in function of the other; provide direct movements in $_{(t-1)}$, in contrast to $_{(t-2)}$ which give an indirect movement. A lagging effect may be a possible cause of this behavior with the spot-futures dynamics as stated by Silvapulle and Moosa (1999). This information is worthy for those trading and hedging within the futures market, specifically within periods of active fed fund rate movements.

Impulse response functions might be used to visually represent the behavior of the aforementioned series (fed fund rates and crude oil future prices) in response to various shocks (within each other and between each other). Figure 4.6a trough 4.6d shows the impulse response functions and their upper and lower bands. If the upper and lower bands cross the horizontal axis, the response becomes statistically insignificant.

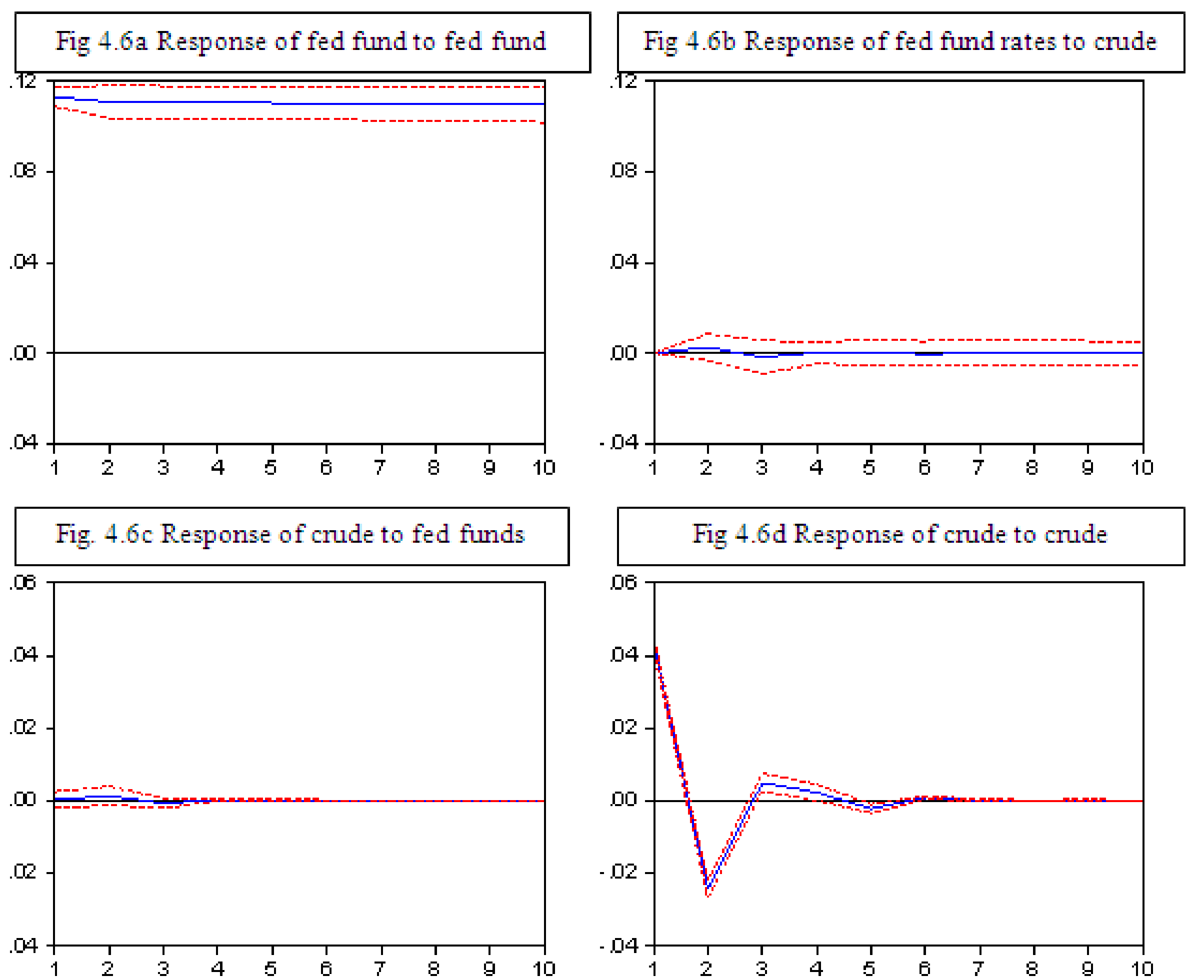
Figure 4.6a shows the response of the fed fund rate within its own market, no peak effect is shown, and while it has a behavior distant from the x – axis, it shows statistical significance of the effects prior days trading carry in current day trading.

Figure 4.6b shows the response of the fed fund rates to the crude oil futures market, it shows statistical significance of the shocks, yet these shocks are relatively small, but do affect for continuous time periods. This can be attributed to the continuous inverse effect the fed fund has on the crude oil futures market.

Figure 4.6c shows the response of the crude oil futures market to the fed fund rate market, there is little to no shock, and becomes statistically insignificant after the third trading day. This is very common in the securities market, since most of the information is carried in the securities price for a time horizon of 2 – 3 trading days (Ming 2008). This analysis confirms the suitability of using two lag days for the VAR model analysis.

Figure 4.6d shows the response of the crude oil futures price within its own market. The peak effect occurs in the 1st trading day and the volatility is present until the 3rd business day (Ming 2008) when the bands cross the x-axis, becoming statistically insignificant after the third day of trading.

Figure 4.6 – Impulse Response Functions



Chapter V: Conclusions and Recommendations

5.1 Conclusions

This research addressed a fundamental question in today's complex financial market environment, that is, how much of the movements of the crude oil futures price can be explained with movements in the fed fund rate market. Using the daily time series for fed fund rates, a proxy for the United States monetary policy and the crude oil futures price, a VAR model was proposed to analyze the relationship within them. This, in an attempt to explain how much of the volatility of the crude oil futures market can be explained with movements in the fed fund rate.

Stationarity was tested trough ADF, ADF at 1st level, and KPSS unit root tests. Fed fund rates presented a stationary time series, which was likely due to the behavior observed in Figure 4.1. In contrasts, crude oil price futures time series plot showed strong volatility within the time period, as observed in Figure 4.2; thus the time series needed to be decomposed. The trend and cyclical components where decomposed using the Hodrick – Prescott filter. Using a log function, the trend was decomposed eliminating fluctuations, creating a trend line along the time series plot. The cyclical or seasonal component was decomposed using the dif-log the time series plot, eliminating the volatility of the graph and providing stationarity to the crude oil futures price time series.

Although the purpose of this research is to explain the impact of monetary policy to the crude oil futures market, a broader perspective was envisioned. Taking into consideration the methodology employed in Brown and Curci (2002, 2004), the VAR model analyzed both stationary time series intended to explain the relationship that exists with the variables, both as a function of each other, and within their own markets.

Empirical results were obtained in which the main question was addressed. Crude oil futures price movements can be explained with movements in the fed fund rate market, specifically a direct relationship in crude oil futures price$_{(t-1)}$ and an indirect relationship in crude oil futures price$_{(t-2)}$. The relationships of both variables were statistically significant, as a function of the other and within their respective markets. A mirror effect is obtained when analyzing the variables as a function of each other.

In conclusion, the literature review lacuna that existed in the topic was partially analyzed using public data within a suitable methodology. The empirical results provided enough evidence to conclude that monetary policy partially explains crude oil futures, which consequently should affect the spot market (Silvapulle and Moosa, 1999; and Ming, 2008). This scenario and the dynamic of these markets are vital and contribute to an objective framework to the discussion that Puerto Rico should be engaging in conversations of alternative crude oil markets to diversify the exposure the United States Monetary policy give the crude oil futures market.

5.2 Areas of Future Research

The areas of future research in this topic should address fundamental analysis, incorporating the spot price of crude oil, in order to obtain the relationships of the primary market in which crude oil, as a commodity, trade within. These will strength the scope of empirical analysis of the dynamic with monetary policy and crude oil trading.

This research can also be used as the basis for further investigations of monetary policy effects on other commodities, which can incorporate further qualitative and quantitative variables with longer time series. For example, there are additional quantitative variables that might affect the strong volatility of crude oil, such as, crude oil spot prices, crude oil option prices, supply and demand quantities, monetary mass, and the countries' Gross Domestic Product (GDP). Similarly, there are qualitative variables that affect volatility, among others, wars (Kafarnaun, Afghanistan, and Middle East conflict) and Federal Open Market Committee (FOMC) meetings. This was an important aspect researched by Horan, Peterson, and Mahar (2004) and can be applied to this topic for deeper analysis.

Finally, as mentioned earlier in this research (Chapter I), policymakers and the general public, are in the outlook on the behavior of crude oil and its financial derivatives, and those activities that affect their behavior. With the results of this research, an empirical analysis showed how the United States monetary policy, a tool used to stimulate the economy, adversely affects the prices for crude oil, an indispensable commodity for consumers. Therefore, a final recommendation is the use of this research as the basis for the debate of monetary policy decisions, specifically those that will determine the banking reserve requirements, which engender fed fund rates fluctuation in the interest rate market. As for the domestic scenario, this analysis is pertinent to the debate of public policy in Puerto Rico, considering the dependence it has on crude oil, as an imported fossil.

Bibliography

Abosedra, S. (2005). Futures versus univariate forecast of crude oil prices. *OPEC Review* ,29(4), 231-240.

Akram, F. Q. (2008). Commodity prices, interest rates, and the dollar. Oslo, Norway: Norges bank. Working Paper, Issue 12

Anderson, D., Sweeney, D., & Williams, T. (2006). *Essentials Statistics for Business and Econmics* (4e ed.). United States: South Western.

Ahumada, H., & Garegnani M. (1999).Hodrick-Prescott Filter in Practice. Journal of Econometrics, 7 (4), 118-147.

Barsky, R., & Kilian, L. (2004). Oil and Macroeconomy since the 1970's. *Journal of Economic Perspectives , 18* (4), 115-134.

Brown, C., & Curci, R. (2004). Brazilian Reals futures trading and volatility in the brazilian equity market. *International Finance Review , 5*, 99-111.

Brown, C., & Curci, R. (2002). Mexican Peso Futures and Exchange Rate Volatility. *Latin American Business Review , 3* (1), 75-90.

Brooks, C. (2008). Intoductory Econometrics for Finance (2 ed.). Cambridge.

Crespo-Cuarsema, J., Jumah, A., & Karbuz, S. (2009). Modeling and Forecasting Oil Prices: The Role of Assymetric Information. *The Energy Journal , 30* (3), 81-91.

Dawson, J. W. (2007). Regulation and the Macroeconomy. *Kylkos* , 60 (1),15-36.

Dickey, D. a. (1979). Distribution of the Estimators for Autoregressive Time Series with a Unit Root. Journal of the American Statistical Association , 74 (366), 427-431.

Diebold, F. X., & Killian, L. (2000). Unit-Root Test are Useful for Selecting Forecasting Models. Journal of Business and Economics Statistics, 18, 265-273.

Frankel, J. A. (2006). The Effect of Monetary Policy on Real Commodity Prices. NBER , 30 (12).

Guidolin, M., & Timmermann, A. (2009). Forecasts of US Short-term Interest Rates: A Flexible Forecast Combination Approach. *Journal of Econometrics* ,150, 297-311.

Horan, S., Peterson, J., & Mahar, J. (2004). Implied Volatility of Oil Futures Options Surrounding OPEC Meetings. *The Energy Journal* , 25 (3), 103-124.

Kandil, M. (2006). On the transmission of exchange rate fluctuations to the macroeconomy: Contrasting evidence for developing and developed countries . *The Journal of International Trade & Economic Development* , 15 (1), 101-127.

Kuang, L. C. (2009). Do macroeconomic variables have regime-dependent effects on stock return dynamics? Evidence from the Markov regime switching model . *Economic Modeling* , 26 (6), 1283-1299.

Lizardo, R. A., & Mollick, A. V. (2009). Do foreign purchases of U.S. stocks help the U.S. stock market? Journal of International Financial Markets, Institutions, and Money .

Ming, Y. L. (2008). The dynamics of the relationship between spot and futures markets under high and low variance regimes. *Applied Stochastic Models in Business and Industry* , 25 (6), 696-718.

Mishkin, F. S., & White, E. N. (2002, June). U.S. STOCK MARKET CRASHES AND THEIR AFTERMATH: IMPLICATIONS FOR MONETARY POLICY. Cambridge, MA, United States.

Mishkin, F. (1998). *The Economics of Money, Banking, and Financial Markets* (5th ed.). New York: Columbia University.

Maede, N. (2000). Evidence for the Selection of Forecasting Methods. Journal of Forecasting , 24 (1), 23-51.

Moshiri, S., & Foroutan, F. (2006). Forecasting nonlinear Crude Oil Futures Prices. *The Energy Journal* , 27 (4), 81-95.

Pindyc, R. (2001). The Dynamic of Commodity Spot and Futures Market: A Primer. *The Energy Journal , 22* (3), 1-29.

Rao, B. B. (2006). Time Series Econometrics and Applied Economic: A Methodological Perspective. Indian Journal of Economics and Business .

Reserve, F. (2009, November 24). *Board of the Governors of the Federal reserve System*. Retrieved November October 1-25, 2009, from Federal Reserve System: http://www.federalreserve.gov/monetarypolicy/default.htm

Soydemir, G. (2000). International transmission mechanism of stock market movements: Evidence from Emerging Equity Markets. *Journal of Forecasting , 19* (3), 149-176.

Shawky, H., Marathe, A., & Barrett, C. (2003). A first look at the empirical relation between spot and futures electricity prices in the United States. *Journal of futures markets , 23* (10), 931-955.

Silvapulle, P., & Moosa, I. (1999). The Relationship between spot and futures prices: Evidence from the Crude Oil Market. (I. Jon Wiley and Sons, Ed.) *The Journal of Futures Market , 19* (2), 175-193.

Simpson, M., & Sanjay, R. (2003). An Examination of the Impact of Macroeconomic News on the spot and futures Treasuries Markets. *The Journal of Futures Markets* ,24 (5), 454-478.

Sundarisan, M. (2006). The relationship between spot and futures prices in stock index futures markets: some prelimenary evidence. *Journal of futures markets , 3* (1), 15-41.

Appendix

Appendix 1 Augmented Dickey-Fuller (ADF) at level test (fed fund rates)

Null Hypothesis: RATES has a unit root
Exogenous: Constant
Lag Length: 7 (Automatic based on SIC, MAXLAG=23)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.131845	0.9441
Test critical values:	1% level	-3.434528	
	5% level	-2.863273	
	10% level	-2.567741	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RATES)
Method: Least Squares
Date: 02/16/10 Time: 19:24
Sample (adjusted): 10/13/2003 6/29/2009
Included observations: 1491 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RATES(-1)	-0.000197	0.001495	-0.131845	0.8951
D(RATES(-1))	-0.094978	0.025782	-3.683913	0.0002
D(RATES(-2))	-0.229894	0.025899	-8.876496	0.0000
D(RATES(-3))	-0.229224	0.026557	-8.631383	0.0000
D(RATES(-4))	-0.181780	0.026797	-6.783582	0.0000
D(RATES(-5))	0.042193	0.026543	1.589603	0.1121
D(RATES(-6))	-0.004107	0.025879	-0.158699	0.8739
D(RATES(-7))	-0.132472	0.025759	-5.142779	0.0000
C	-0.000393	0.005148	-0.076249	0.9392

R-squared	0.137006	Mean dependent var	-0.000523
Adjusted R-squared	0.132347	S.D. dependent var	0.110988
S.E. of regression	0.103383	Akaike info criterion	-1.694731
Sum squared resid	15.83974	Schwarz criterion	-1.662696
Log likelihood	1272.422	Hannan-Quinn criter.	-1.682793
F-statistic	29.40958	Durbin-Watson stat	1.983311
Prob(F-statistic)	0.000000		

Appendix 2 Augmented Dickey-Fuller (ADF) at 1st level (fed fund rates)

Null Hypothesis: D(RATES) has a unit root
Exogenous: Constant
Lag Length: 6 (Automatic based on SIC, MAXLAG=23)

		t-Statistic
Augmented Dickey-Fuller test statistic		-19.16859
Test critical values:	1% level	-3.434528
	5% level	-2.863273
	10% level	-2.567741

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RATES,2)
Method: Least Squares
Date: 02/16/10 Time: 19:26
Sample (adjusted): 10/13/2003 6/29/2009
Included observations: 1491 after adjustments

Variable	Coefficient	Std. Error	t-Statistic
D(RATES(-1))	-1.831259	0.095534	-19.16859
D(RATES(-1),2)	0.736107	0.087449	8.417556
D(RATES(-2),2)	0.506041	0.077953	6.491624
D(RATES(-3),2)	0.276645	0.064929	4.260755
D(RATES(-4),2)	0.094713	0.051355	1.844275
D(RATES(-5),2)	0.136780	0.038195	3.581058
D(RATES(-6),2)	0.132568	0.025740	5.150272
C	-0.000972	0.002677	-0.363164

R-squared	0.577102	Mean dependent var
Adjusted R-squared	0.575106	S.D. dependent var
S.E. of regression	0.103349	Akaike info criterion
Sum squared resid	15.83992	Schwarz criterion
Log likelihood	1272.413	Hannan-Quinn criter.
F-statistic	289.1085	Durbin-Watson stat
Prob(F-statistic)	0.000000	

Appendix 3 Kwiatkowski – Phillips – Schmidt – Shin (KPSS) test (fed fund rates)

Null Hypothesis: RATES is stationary
Exogenous: Constant
Bandwidth: 31 (Newey-West using Bartlett kernel)

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		1.156751
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Residual variance (no correction)	3.234967
HAC corrected variance (Bartlett kernel)	101.4454

KPSS Test Equation
Dependent Variable: RATES
Method: Least Squares
Date: 02/16/10 Time: 19:27
Sample (adjusted): 10/01/2003 6/29/2009
Included observations: 1499 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.927145	0.046471	62.98907	0.0000

R-squared	0.000000	Mean dependent var	2.927145
Adjusted R-squared	0.000000	S.D. dependent var	1.799202
S.E. of regression	1.799202	Akaike info criterion	4.013230
Sum squared resid	4849.216	Schwarz criterion	4.016774
Log likelihood	-3006.916	Hannan-Quinn criter.	4.014550
Durbin-Watson stat	0.003786		

Appendix 4 Augmented Dickey-Fuller (ADF) at level test (fed fund rates)

Null Hypothesis: PRICES has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic based on SIC, MAXLAG=23)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.569825	0.4978
Test critical values:	1% level	-3.434692	
	5% level	-2.863345	
	10% level	-2.567780	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(PRICES)
Method: Least Squares
Date: 02/16/10 Time: 18:10
Sample (adjusted): 10/06/2003 4/07/2009
Included observations: 1437 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
PRICES(-1)	-0.004006	0.002552	-1.569825	0.1167
D(PRICES(-1))	-0.489568	0.026258	-18.64486	0.0000
D(PRICES(-2))	-0.115009	0.026228	-4.384936	0.0000
C	0.305036	0.172893	1.764303	0.0779

R-squared	0.206336	Mean dependent var	0.033410
Adjusted R-squared	0.204674	S.D. dependent var	2.726269
S.E. of regression	2.431314	Akaike info criterion	4.617521
Sum squared resid	8470.878	Schwarz criterion	4.632191
Log likelihood	-3313.689	Hannan-Quinn criter.	4.622998
F-statistic	124.1833	Durbin-Watson stat	2.015381
Prob(F-statistic)	0.000000		

Appendix 5 Augmented Dickey-Fuller (ADF) at 1st level (fed fund rates)

Null Hypothesis: D(PRICES) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic based on SIC, MAXLAG=23)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-36.10278	0.0000
Test critical values:	1% level	-3.434692	
	5% level	-2.863345	
	10% level	-2.567780	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(PRICES,2)
Method: Least Squares
Date: 02/16/10 Time: 18:12
Sample (adjusted): 10/06/2003 4/07/2009
Included observations: 1437 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(PRICES(-1))	-1.607740	0.044532	-36.10278	0.0000
D(PRICES(-1),2)	0.115977	0.026234	4.420803	0.0000
C	0.053000	0.064186	0.825725	0.4091

R-squared	0.724041	Mean dependent var	0.001072
Adjusted R-squared	0.723656	S.D. dependent var	4.627406
S.E. of regression	2.432555	Akaike info criterion	4.617847
Sum squared resid	8485.445	Schwarz criterion	4.628850
Log likelihood	-3314.923	Hannan-Quinn criter.	4.621955
F-statistic	1881.210	Durbin-Watson stat	2.015672
Prob(F-statistic)	0.000000		

Appendix 6 Kwiatkowski – Phillips – Schmidt – Shin (KPSS) test (crude oil futures price)

Null Hypothesis: D(PRICES) is stationary
Exogenous: Constant
Bandwidth: 9 (Newey-West using Bartlett kernel)

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.136652
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Residual variance (no correction)	7.417064
HAC corrected variance (Bartlett kernel)	2.393254

KPSS Test Equation
Dependent Variable: D(PRICES)
Method: Least Squares
Date: 02/16/10 Time: 18:13
Sample (adjusted): 10/02/2003 4/07/2009
Included observations: 1439 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.033280	0.071819	0.463391	0.6432

R-squared	0.000000	Mean dependent var	0.033280
Adjusted R-squared	0.000000	S.D. dependent var	2.724376
S.E. of regression	2.724376	Akaike info criterion	4.843050
Sum squared resid	10673.16	Schwarz criterion	4.846714
Log likelihood	-3483.575	Hannan-Quinn criter.	4.844418
Durbin-Watson stat	2.880959		

Appendix 7 Augmented Dickey – Fuller unit root test (dif-log)

Null Hypothesis: DIFLOG has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic based on SIC, MAXLAG=23)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-40.79058	0.0000
Test critical values:	1% level	-3.434689	
	5% level	-2.863344	
	10% level	-2.567779	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(DIFLOG)
Method: Least Squares
Date: 04/11/10 Time: 17:45
Sample (adjusted): 10/02/2003 4/06/2009
Included observations: 1438 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DIFLOG(-1)	-1.073518	0.026318	-40.79058	0.0000
C	0.000759	0.000508	1.494911	0.1352

R-squared	0.536755	Mean dependent var	1.20E-06
Adjusted R-squared	0.536432	S.D. dependent var	0.028267
S.E. of regression	0.019246	Akaike info criterion	-5.061665
Sum squared resid	0.531892	Schwarz criterion	-5.054334
Log likelihood	3641.337	Hannan-Quinn criter.	-5.058928
F-statistic	1663.872	Durbin-Watson stat	1.993246
Prob(F-statistic)	0.000000		

Appendix 8 – Augmented Dickey – Fuller test at 1st level (dif-log)

Null Hypothesis: D(DIFLOG) has a unit root
Exogenous: Constant
Lag Length: 14 (Automatic based on SIC, MAXLAG=23)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-18.89519	0.0000
Test critical values:	1% level	-3.434737	
	5% level	-2.863365	
	10% level	-2.567790	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(DIFLOG,2)
Method: Least Squares
Date: 04/11/10 Time: 17:42
Sample (adjusted): 10/23/2003 4/06/2009
Included observations: 1423 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(DIFLOG(-1))	-10.12583	0.535895	-18.89519	0.0000
D(DIFLOG(-1),2)	8.097534	0.524531	15.43767	0.0000
D(DIFLOG(-2),2)	7.162127	0.503189	14.23347	0.0000
D(DIFLOG(-3),2)	6.268104	0.474801	13.20153	0.0000
D(DIFLOG(-4),2)	5.434715	0.441070	12.32167	0.0000
D(DIFLOG(-5),2)	4.638744	0.403014	11.51014	0.0000
D(DIFLOG(-6),2)	3.894833	0.361599	10.77114	0.0000
D(DIFLOG(-7),2)	3.241878	0.318336	10.18381	0.0000
D(DIFLOG(-8),2)	2.611975	0.273932	9.535120	0.0000
D(DIFLOG(-9),2)	2.000867	0.228484	8.757131	0.0000
D(DIFLOG(-10),2)	1.482241	0.183237	8.089223	0.0000
D(DIFLOG(-11),2)	1.029349	0.139412	7.383495	0.0000
D(DIFLOG(-12),2)	0.620396	0.097814	6.342632	0.0000
D(DIFLOG(-13),2)	0.306152	0.059761	5.122917	0.0000
D(DIFLOG(-14),2)	0.113971	0.026519	4.297705	0.0000
C	-2.03E-05	0.000521	-0.038906	0.9690

R-squared	0.847854	Mean dependent var	2.49E-07
Adjusted R-squared	0.846232	S.D. dependent var	0.050155
S.E. of regression	0.019667	Akaike info criterion	-5.008525
Sum squared resid	0.544239	Schwarz criterion	-4.949376
Log likelihood	3579.565	Hannan-Quinn criter.	-4.986431
F-statistic	522.7119	Durbin-Watson stat	2.006245
Prob(F-statistic)	0.000000		

Appendix 9 – Kwiatkowski – Phillips –Schmidt – Shin unit root test (dif-log)

Null Hypothesis: D(DIFLOG) is stationary
Exogenous: Constant
Bandwidth: 50 (Newey-West using Bartlett kernel)

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.017843
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Residual variance (no correction)	0.000798
HAC corrected variance (Bartlett kernel)	1.48E-05

KPSS Test Equation
Dependent Variable: D(DIFLOG)
Method: Least Squares
Date: 04/11/10 Time: 17:11
Sample (adjusted): 10/02/2003 4/06/2009
Included observations: 1438 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.20E-06	0.000745	0.001607	0.9987

R-squared	0.000000	Mean dependent var	1.20E-06
Adjusted R-squared	0.000000	S.D. dependent var	0.028267
S.E. of regression	0.028267	Akaike info criterion	-4.293557
Sum squared resid	1.148187	Schwarz criterion	-4.289891
Log likelihood	3088.067	Hannan-Quinn criter.	-4.292188
Durbin-Watson stat	3.115897		

Appendix 10 Vector Autoregression (VAR) estimates analysis output

Vector Autoregression Estimates
Date: 04/10/10 Time: 17:25
Sample (adjusted): 10/07/2003 4/07/2009
Included observations: 1436 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	Rates	Price
Rates(-1)	0.980418	0.011994
	(0.02642)	(0.01007)
	[37.1054]	[1.19144]
Rates(-2)	0.018011	-0.011997
	(0.02644)	(0.01007)
	[0.68133]	[-1.19122]
Prices(-1)	0.060963	-0.566661
	(0.06787)	(0.02586)
	[0.89825]	[-21.9149]
Prices(-2)	-0.066896	-0.207097
	(0.06792)	(0.02588)
	[-0.98487]	[-8.00271]
C	0.004196	0.001276
	(0.00601)	(0.00229)
	[0.69831]	[0.55763]
R-squared	0.995817	0.254362
Adj. R-squared	0.995805	0.252278
Sum sq. resids	18.27872	2.653215
S.E. equation	0.113019	0.043059
F-statistic	85162.16	122.0405
Log likelihood	1095.669	2481.385
Akaike AIC	-1.519038	-3.449004
Schwarz SC	-1.500690	-3.430655
Mean dependent	3.045320	0.000713
S.D. dependent	1.744981	0.049796

Determinant resid covariance (dof adj.)	2.37E-05
Determinant resid covariance	2.35E-05
Log likelihood	3577.072
Akaike information criterion	-4.968067
Schwarz criterion	-4.931371

Appendix 11 VAR model equations

VAR Model:
===============================
Fed Fund Rates = C(1,1)*Fed Fund Rates(-1) + C(1,2)*Fed Fund Rates(-2) + C(1,3)*Crude Oil Futures Price(-1) + C(1,4)*Crude Oil Futures Price(-2) + C(1,5)

Crude Oil Futures Price = C(2,1)*Fed Fund Rates(-1) + C(2,2)*Fed Fund Rates(-2) + C(2,3)*Crude Oil Futures Price(-1) + C(2,4)*Crude Oil Futures Price(-2) + C(2,5)

VAR Model - Substituted Coefficients:
===============================
Fed Fund Rates = 0.980417668802*Fed Fund Rates(-1) + 0.0180109347292*Fed Fund Rates(-2) + 0.060963404594*Crude Oil Futures Price(-1) - 0.0668963335623*Crude Oil Futures Price(-2) + 0.00419557059766

Crude Oil Futures Price= 0.0119939018232*Fed Fund Rates(-1) - 0.0119974120578*Fed Fund Rates(-2) - 0.566661475441*Crude Oil Futures Price(-1) - 0.207097274583*Crude Oil Future(-2) + 0.0012764458493