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Comparison of Hedging Strategies on Raw Material Futures

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Abstract

The objective of this master thesis realised with BNP Paribas Fortis is to create a hedging strategy on a determined commodity which takes the currency risk into account. We choose the Brent Oil as commodity and the Euro Dollar exchange rate. To reach this objective, we develop an indicator to detect the periods where the currency risk has to be hedged. We use PCA, correlation analysis, linear regressions and we study the impact of the futures term structure on the profitability of a hedging strategy. After that, we compare different techniques to hedge the commodity risk and the currency risk with futures, options and forward contracts. Some statistical ways to work out the optimal hedge ratio as GARCH, naïve approach and rolling window are also compared and we choose the most effective one in our case. Finally we make two simulations with the two risks together. This master thesis is a summary of the steps that have to be taken by an European SME which has to create an hedging strategy.

The conculsion of this master thesis is that it is interresting to play with the slope of the futures prices curve. A hybrid strategy which plays with the differences of maturities can be, on average, a good compromise between reduction of variance and reduction of the average barrel price. The choice of the maturity is different if the market is in contango or in backwardation. Moreover our indicator detects when the Euro Dollar exchange rate could know important variations.

Acknowledgement

After studying five years at the university, students have to write a master thesis which shows all the knowledge and the experiences they have gathered during this education. We decided to make our master thesis on a financial issue with the collaboration of Mister Dirk-Emma Baestaens (Head of the Client-Solution Development Group of BNP Paribas Fortis), Professor Catherine D'Hondt and Professor Mikael Petitjean of the Louvain School of Management. I heartily thank them for their help during my internship and my project.

I also thank Mrs Lisiane Berteau and my parents for their help during the drafting of my master thesis. This work would not have been possible without their support.

Table of contents

List of the figures

List of the tables

I. Introduction and objectives

The objective of our master thesis consists in developing a hedging strategy on a particular commodity taking into account the currency risk as well. This hedging strategy could be used by European companies which have to buy petroleum for their activities. So we consider importations of commodity and not the exportations. To sum up, this master thesis summarizes some of the most important ways to create a hedging strategy with those two dimensions: the commodity risk and the currency risk.

As a commodity, we select the petroleum and in particular the Brent crude oil because of the interest of BNP Paribas Fortis in this asset. They have indeed a lot of clients who have direct and indirect financial exposures to the evolutions of the crude oil market.

To reach our objective, a large part of our work consists of some research on the Brent oil market, its main variables and a summary of the essential things to know before coming into this particular market. For example, the slope of the futures prices curve, the correlations between oil price and others assets, the determinants of the price and other elements.

Another aspect of this master thesis is to work with another dimension: the exchange rate effect. The European Brent crude oil is traded in dollar, so the Euro Dollar exchange rate (Eurodoll) has also an impact on the final price for the European consumers. Moreover, we have done our internship in a fixed income department, so it is why we insist on this part. Thanks to this master thesis, the clients of the department could easily determine if we are in a period which presents a significant currency risk or not.

We also compare some typical hedging strategies used to cover the positions of the companies in the commodity market. We have decided to insist on the use of futures and forward contracts even if we also shortly analyze the use of options.

Finally, we select the "best" hedging strategy that is identified and we make a simulation with the introduction of the currency hedge, transactions costs, momentum signals and other dimensions. We develop those points later in our thesis to make our analysis more realistic without making a too specific case.

The structure of our master thesis is divided into three main parts: the history of the oil market, the theoretical part and the practical part. We begin with the history, the context of the oil market and the correlation. After that we see all the theoretical elements we use: conditional volatility, statistical techniques (PCA), derivatives, hedging strategies and the term structure of the futures prices together. After that, we use all this elements to reach our objective in the practical part.

All the calculations and the statistical models used are selected with a concern of simplicity at the request of BNP Paribas Fortis. We try to be the clearest possible to be sure that our work could be understood by everybody who would only have limited knowledge in finance. Indeed, the objective of this project is to obtain a strategy which could be directly used by middle or small companies. Those companies have only a limited exposure to crude oil price and whose core business does not consist in trading on commodities or foreign exchanges markets.

You can find all the calculation on the Excel files called: "Results _Benjamin_Brine.xls", "Periods_Benjamin_Brine.xls" and "Simulations_Benjamin_ Brine.xls" which are available on the attached CD. This CD contains the complete SAS outputs for some appendices too.

II. History and Context

Some theoretical principles are used in the practical part of our master thesis. For purpose of clearness we have decided to get through the needed elements in two parts: the history and the context of the oil market and the theoretical principles. The history of the oil market is developed in this part without going into small details.

Other theoretical principles like multicolinearity, stationnarity, significance and linear regression are directly used in the practical part. Our aim is to address directly the core of this thesis without going too far into mathematical and econometrical theory.

a) Oil Market

1) *Background and commodity risk*

It is really important to understand the market on which we have to develop a hedge. It is the objective of this part. However we are not going to tell the whole story of the oil market with the oil shocks because it would take too long and it is not the point here.

It is impossible to analyze any aspect of the economy without speaking about growth, production, revenue, transport… And oil price has an impact on all these terms.[1] Therefore, everyone has to consider this commodity in each aspect of his life. So, our way of life, our consumption model is only possible thanks to fossil fuels but the reserves of this kind of energy are not infinite[2]. It is why we will have some problems to replace them even if the technology or Bio fuels become more and more efficient through years. Our society would need more than 20 years to adapt the

[1] « IV. Évolution des prix du pétrole : moteurs, conséquences économiques et ajustement des politiques», Perspectives économiques de l'OCDE, 2004/2 no 76, p. 147-170.
[2] ibidem

consumption model and the infrastructures to replace fossil petroleum[3]. It is why it is important to know the variables which could explain the variations of the oil price in the short and the long run.

In the short term, the oil price has an important impact on the profitability of companies and the purchasing power of households[4]. Moreover the changes in demand or in supply on the crude oil market for example have an impact on the fuel price. A change in the supply could come from a political change in some OPEC countries, a war or exceptional weather conditions[5]. Another important factor is the level of the oil reserves of OPEC countries. When it is very low, the investors worry about a possible shortfall in the oil supply and there is a direct impact on the price[6].

As far as the demand is concerned it is easy to explain its dependence on the fuel price. The industry uses crude oil or petroleum derivatives for its activity and it is impossible for plants to use other sources of energy in a relative short period of time: they have to buy petroleum whatever the price.[7] This principle is also useful to explain the concept of convenience yield (see later in this thesis). The shocks in supply or in demand are very dangerous for the companies because they quickly lead to a significant change in the oil price. And a small change in the crude oil price (increase or decrease) has a direct impact on the profitability for crude petrol buyers and sellers.

In the long run, the petroleum price has been increasing for more than twenty years and the forecasts are not optimistic for the future[8]. The growth of emerging countries needs a lot of fuel and the changes in the technologies of production and consumption is not possible in less than twenty or thirty years[9]. As we said before, our economic model is based on the oil use, and the reserves or production capacities are not infinite. Moreover, the world consumption of petroleum has been increasing

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[3] Houssin Didier, « Vers la fin du pétrole ? », Études, 2005/11 Tome 403, p. 463-474.
[4] « IV. Évolution des prix du pétrole : moteurs, conséquences économiques et ajustement des politiques», Perspectives économiques de l'OCDE, 2004/2 no 76, p. 147-170.
[5] Ibidem
[6] Ibidem
[7] J. Hull, « Options, Futures and other derivatives », New Jersey, Pearson, 8th edition, 2011.
[8] BNP Paribas, « Commodity Market: Oil outlook 2013 and beyond", presentation, 2013.
[9] Houssin Didier, « Vers la fin du pétrole ? », Études, 2005/11 Tome 403, p. 463-474.

quicker than the amount of the new discovered reserves for some years[10]. In other words: we are using more than we find. What is rare is expensive, and oil will become rarer and rarer over years and it could mean a real change in our society for the next decades.

Another aspect is that this asset is more than an economic asset; it is also a financial asset. Thousands of people trade on the oil price every day and it has a direct and indirect impact on the price. Indeed, we read a lot of papers and theses about the impact of speculation on the prices of the commodities[11]. It seems that there is a link between speculation and the volatility of prices even if it is not scientifically proven[12]. Indeed, it is logical that more speculation could mean more price fluctuations: The speculators try to increase the price movements because the principle of speculation is to take benefits from price changes[13]. This is the opposite principle to hedging whose purpose is to get protected against price fluctuations.

For all those reasons, it is clear that it is important to have a protection against the oil prices volatility which is also called commodity hedge. It is a fact that the oil price will rise in the long term and any protection could be efficient enough against this problem except a radical change in our consumption[14] or a very expensive long term hedging policy. Nevertheless, in the short term (for example a break in the production during several months, a climatic disaster, and so on), it is possible to be protected and it is the object of this thesis.

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[10] « IV. Évolution des prix du pétrole : moteurs, conséquences économiques et ajustement des politiques», Perspectives économiques de l'OCDE, 2004/2 no 76, p. 147-170.
[11] Ibidem
[12] Ibidem
[13]W. Labys and C. Granger, « Speculation, Hedging and Commodity Price Forecast », Ed. Health Lexington Book, 1970.
[14] « IV. Évolution des prix du pétrole : moteurs, conséquences économiques et ajustement des politiques», Perspectives économiques de l'OCDE, 2004/2 no 76, p. 147-170.

2) *The Brent oil*

There are many varieties of oil traded on the market. The most important ones are the Western Texas Intermediate (WTI), which is extracted in the United States and the Brent oil, which is a blend of petroleum extracted in the North Sea[15].

We have decided to make our study on the Brent oil because it is the one we use in our countries and because it was asked by BNP Paribas Fortis. This petroleum is made from a mix of different raw oils that are all extracted from the North See by countries like the United Kingdom and Norway.[16]

Even if the petroleum which makes up the Brent is extracted in Europe, it becomes a world reference thanks to financial markets. It is due to the fact that the Brent blend oil futures are the most exchanged ones in the crude oil futures family. There is more information over the Brent oil (volume and markets) in appendix n°001.

3) *Currency risk*

We said before in this master thesis that there are two principal risks that a European company which has to buy or sell petroleum has to take into account: the commodity risk and the currency risk[17].

Even if we have already spoken about the commodity risk (production problem, war, disequilibrium between demand and supply…), the currency risk is also really important even if it is often neglected or misunderstood.

The importance of the currency risk for European companies can be explained by the fact that Brent oil is quoted in Dollar and the majority of European companies

[15] U.S. Energy Information Agency,< http://www.eia.gov/dnav/pet/TblDefs/pet_pri_spt_tbldef2.asp>, Page accessed on the 15th April 2013.
[16] Ibidem
[17] S. Myint and F Famery, « Corporate Financial Risk Management », Ed Risk Book in collaboration with BNP Paribas, 2012

makes their operations in Euro. The Euro Dollar exchange rate has unavoidably an impact on the price paid by European consumers.

We have decided to address this subject because we have read in documents of BNP Paribas Fortis that it is often advised to companies to hedge the currency risk and the commodity risk together or to do nothing at all.[18] The aim is to take profit from the economies of scales in the volatility reduction. We wanted to make some research about this advice because it seemed a little bit too reductive for us. Therefore we have decided to create a more efficient hedging strategy than the Manichean one (total hedge or no hedge).

b) Correlation between Brent Price and Euro Dollar exchange rate

As we just have mentioned in the introduction of our thesis, one objective of this work is to take the currency risk into account. In other words, we want to separate the currency risk from the commodity risk on the Brent quoted in Dollar which is converted in Euro. We explain in this part how the correlation can be a suitable instrument to do that.

Currencies and commodities are very closely linked. For example, when a country is an important producer of a commodity, there is a link between its currency value and the price of its production[19]. For example, there is a link between the silver price and the Mexican Peso because Mexico is an important producer of silver. In our case, we will focus on the correlation between the Euro Dollar exchange rate and the Brent Crude oil. But why do we believe that there is a correlation between the Brent oil (European Oil) and the Euro Dollar exchange rate? We have detected two main reasons during our work.

[18] S. Myint and F Famery, « Corporate Financial Risk Management », Ed Risk Book in collaboration with BNP Paribas, 2012

[19] R. Noirfalise, "Alternatives to direct commodities hedging: A silver conditional volatility based approach", Master Thesis, UCL-Mons, 2012.

First one: the United States are the first oil consumers in the world[20] and the first economy in the world too, so there could be a link between the US currency and the Brent oil price which is the most international crude oil value.[21]

Second one: the Brent spot price and Futures prices are quoted in Dollar. If a European company buys some Brent Futures or uses Brent oil for consumption it is normal and logical that the Euro Dollar exchange rate has an impact on the real fuel price in Euro and on European consumers by translation. For example: with no change in commodity price, a weak Euro means that the Euro Dollar exchange rate is lower, so the cost of the barrel is higher in with no change of the price in dollar.

Even if the correlation between the Dollar currency (and so the Euro Dollar exchange rate by translation) and the oil price was historically quite stable in the past, it tends to decrease for ten years[22].This is due in part to the growth of the emerging countries, the problems in the oil supply and the growing importance of renewable energies[23]. Nevertheless, it is also important to say that even if this correlation diminishes over years, it always stays significant.

So the changes in the pattern of correlation could mean that there are some important short term changes on the market, which could result in a temporary disequilibrium between some important classes of variables (see practical part). Those analyses of correlations could help us to decide if we have to hedge against a currency risk, a commodity risk or a combination of the two.

The correlation is one of the principles to know before coming into a hedging policy. On the table n°01 you can find the four scenarios that could happen for a company which has to buy a commodity quoted in a foreign currency.[24] We do not consider exportation in our case because it is not the object of this master thesis.

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[20] BNP Paribas, « Commodity Market: Oil outlook 2013 and beyond", presentation, 2013.
[21] ICE, « The Growth of Brent Crude Oil », ICE FUTURES EUROPE, 2013 (see appendix n°001)
[22]P. Artus, «Flash Marchés : Y-a-t-il vraiment un lien entre le prix du pétrole et le taux de change du dollar ? », Natixis, n°98, 2008.
[23] Houssin Didier, « Vers la fin du pétrole ? », Études, 2005/11 Tome 403, p. 463-474.
[24] S. Myint and F Famery, « Corporate Financial Risk Management », Ed Risk Book in collaboration with BNP Paribas, 2012

Table n°01: Correlation pattern

	Commodity price increases	Commodity price decreases
Exchange rate increases	1. Commodity Hedge, high correlation (~1)	2. No hedge at all low correlation (~-1)
Exchange rate decreases	3. Currency hedge, commodity hedge, low correlation (~-1)	4. Currency hedge or no hedge at all, high correlation (~1)

Source: S. Myint and F Famery, « Corporate Financial Risk Management », Ed Risk Book in collaboration with BNP Paribas, 2012

Scenario 1: The exchange rate increases, we do not have to create a currency hedge because we pay less Euro for one Dollar and it is good for us if we are in Europe. However the commodity increase, it is not good for us in case of importation and we have to make a commodity hedge.

Scenario 2: This is the perfect scenario. The exchange rate increase, so we pay less Euro per Dollar, no currency hedge. Moreover the price of the Commodity decreases. We do not have to create a commodity hedge.

Scenario 3: In our case this is the worst scenario. We have to create a currency and a commodity hedge. We pay more Euro per Dollar because the exchange rate decreases and the price of the commodity increases.

Scenario 4: The price of the commodity decreases, so no commodity hedge. However the exchange rate decreases. We could have to create a currency hedge but it depends on the decrease of the commodity. Indeed if it is an important decrease the currency hedge could be quite useless because we already win money thanks to the diminishing of the commodity.

We analyze the correlation to show you that it is not a good idea to automatically hedge our two risks in the case of high correlation: our two variables are going up or our two variables are going down. In the case of a rise, we only make a commodity hedge. In the case of a decrease, we study what could be the best solution. Now we explain the different concepts we use in our project.

III. Theoretical Part

After the context, the history of the oil market and a little summary of the impact of the correlation, we are going to see the theoretical aspects of this thesis. We only focus our mind on the main elements we use in our practical part. We begin with the Principal Component Analysis.

a) Principal components analysis (PCA)

1) *General principle*

We need a way to study the impacts of several variables on a sample of data (We explain this sample in our practical part). As those variables are sometimes strongly correlated, we had to find a way to avoid this correlation.

After some research, we discovered the principal component analysis (PCA). We took some information in the literature before using this technique on SAS with the procedure “FACTOR”. We make the following summary of those documents.

The principle of the PCA method is to reduce an important number of highly correlated variables to a smaller number which is easier to work with. The goal of this method is to determine the principal common trends inside a sample of variables[25]. For example, if we take the daily temperature of the major European cities during some years, it is clear that the number of variables is very important and correlated so it could be really fastidious to take all of them into account. There are two solutions to avoid this important number of data: it is possible to detect some general trends inside all our data (thanks to PCA) or to select the most relevant observations and delete the others[26].

[25] SAS, « Principal Component Analysis », SAS IT Support, <http://support.sas.com/publishing/pubcat/chaps/55129.pdf>
[26] J. Confais and M Le Guen, « Premiers pas en régression linéaire avec SAS », Documents de Travail du Centre d’Economie de la Sorbonne, 2007 < http://ces.univ-paris1.fr/cesdp/CES-docs.htm>

As we said, a solution to our problem could be to select some variables to make our study easier. But a significant disadvantage is that we would lose a lot of information. How could we solve this problem with another method? By using PCA.

The PCA determines common trends into our variables and work out a smaller number of variables called factors which will sum up all the information of our initial sample without losing information.

Each initial variable has a weighted coefficient for each factor. If we take an example for J variables, it is possible to work out the value of each factor for each period of time by applying the equation:

$$Factor_i = w_{i1} * (X_1) + w_{i2} * (X_2) + \cdots + w_{ij} * (X_j) + \varepsilon_i$$

Where:

-$Factor_i$= the value of the i^{th} factor extracted at time t

-w_{ij}: the weight for observed standardized variable Xj at time t associated to factor i (it is also called the standardized scoring coefficient)

-X1 to Xj: the standardized variables (with mean=0 and standard deviation =1)

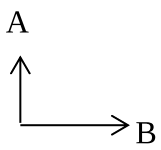
-ε_i is the error

It is simple to observe that the more important is the weight, the more important is the variable to work out the factor. If we follow this way, a sample of N variables could be explained by only a few factors.

Each of those factors explains a proportion of the variance of the global sample. The first factor explains the biggest proportion of the sample’s variance; the second one explains less variance, and so on. To determine the number of the retained factors, you have to determine the proportion of the variance of the sample you want to explain (for example 80, 90 or 95%). You work out the cumulative proportion of the explained variance and stop when you are satisfied.

2) *Rotation principle*

After obtaining the number of factors to retain, we use a method to interpret the results on an easier way and to remove the correlation between factors. We call that "the Varimax rotation method". After the application of this principle, you obtain orthogonal (and so uncorrelated) factors. To understand this, imagine we retain two factors (A and B) after using PCA on a determined number (N) of variables to explain the variance of our sample. Thanks to the rotation, we can represent all our variables with two orthogonal axes A and B like this:



This way, it's possible to represent all our variables with the use of only two variables (our factors) instead of a number N. Each rotated loading (or rotated factor pattern) represents the value of the variable on the axis A and the axis B. This way, we reduce our variables from a number N to two. It is the principle we use in our work even if we retain more than two factors, but the principle is the same for two or N factors.

3) *Performance*

We mostly use one indicator to measure the performance of our PCA. The Kaiser's Measure of Sample Adequacy. This is the indicator we use to determine if it is possible to use PCA in our case. A value of the Overall MSA which is superior to 0.6 indicates that PCA is useful to represent our sample. If it is not the case, it means that PCA is quite useless and it is not a good way to represent the variance of our sample.[27]

We put a complete example of how we use PCA and to understand the interpretations of the results in appendix n°002 of this master thesis for more information and in a purpose of clearness.

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[27] SAS, <http://support.sas.com/documentation/cdl/en/statug/63347/HTML/default/viewer.htm#statug_factor_sect029.htm>, IT Support, page accessed the 3rd February 2013.

b) Derivatives

We use derivatives in our thesis. It seems very important to us to define some aspects and some theoretical principles of those products. We make a small summary over the derivatives we use as futures, options, and forward contracts. We are going to see the main things to know about them.

1) *The futures and the forward markets*

It is almost impossible to make hedging strategies without speaking about futures contracts. If we take the definition given by John Hull in his book "Options Futures and others derivatives": *«A futures contract is a contract between two counterparties to sell or buy a given asset for a given price during a given period*".

It is also important to note that there is a significant difference between the spot price and the futures price. This difference is called the *basis*[28] and it increases with the augmentation of the maturity of the contract (in general). But the futures prices and the spot prices must be the same at maturity. We will come back in detail to this point in the part about the term structure of the futures prices in this thesis.

The difference with the forward contracts is that the forward contracts are not standardized. The other differences are explained in the following table. We will not insist on those derivatives because we have had dedicated courses at the university and only a small summary is needed.

Table n°02: Futures and Forward Differences

Forward contracts	**Futures contracts**
Trade over-the-counter	Trade on an exchange (organized market)
Not standardized	Standardized contracts
One specified delivery date	Range of delivery dates
Settled at the end of a contract	Settled daily
Delivery or final cash settlement usually occurs	Contract usually closed out prior to maturity.
Existence of a Credit risk	Absence (or nearly) of credit risk

Source: J. Hull, « Options, Futures and other derivatives », New Jersey, Pearson, 8th edition, 2011.

[28] J. Hull, « Options, Futures and other derivatives », New Jersey, Pearson, 8th edition, 2011.

2) Options

Options are derivatives which can be used in hedging strategies. It is why we also include this product in our analysis. This part is dedicated to a short explanation of those products.

If we still follow the definition given by John Hull in "Options, futures and other derivatives": *"an option gives the right to his owner to buy or to sell a determined quantity of an asset at a determined price during a period (for American options) or a determined date (for European options)"*

There are essentially two kinds of options: Call options and put options. The call options give a right to buy the asset and the put options give the right to sell.

The major difference is given by John Hull in "Options, futures and other derivatives". The difference between options and futures or forward contracts is that options give a right and no obligation to buy or to sell the asset at a determined price.

An option is like insurance. You pay a premium and you use your right if that leads to a positive impact on your profits. We use the Black, Scholes and Merton model to price our options. We know that there exists others model to price options but we decided to use the Black Scholes valuation model because it is the model we saw during our "Derivatives Securities" course in UCL-Mons. We thought that it was a good opportunity to use the knowledge we learnt during our teaching in University. Even if some of those assumptions are not really respected in our case, we consider that those violations are not so important and that this model gives a good approximation of the option price we wanted to work out.

The assumptions and the formulas used in the Black Scholes and Merton model are in appendix n°003.

c) How to work out correlation and volatility?

We have seen at the beginning of our thesis that the volatility and the correlation between two variables have an important role in the implementation of a hedging strategy. But what are those concepts in detail? We expose the different ways to work out the volatility and the correlation we have found during our research to you.

The volatility of a financial asset could be defined as *"measure of uncertainty about the future profitability of an asset"*[29]. This is associated with a measure of risk. Indeed, a strong volatility means that the price could suffer from strong variations and weak volatility means that it is nearby improbable that important price variations could happen.

In mathematical terms, the correlation between two series of variables X and Y is equal to: $\frac{Covariance\ (X,Y)}{\sigma_X \sigma_Y}$. In this equation, σ is the standard deviation of the series of the variables X or Y.

We are going to see several methods to work out the volatility and the correlation: naïve methods and conditional methods. We speak about the volatility and the correlation together because all of them are statistical principles. The methods to define them are quite similar.

1) *Naïve methods*

The naïve methods expect that the correlation and the volatility which happened in the past will also happen in the future. We made some research about those naïve methods and we detected two among them. Those naïve methods can also be named historical methods.

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[29] J. Hull, « Options, Futures and other derivatives », New Jersey, Pearson, 8th edition, 2011.

A) <u>The naïve constant volatility and correlation.</u>

This method is the most basic and the easiest to understand. You work out the correlation on the data of your complete sample. You only have to use those formulas:

Volatility: $\sigma_x = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})}$

Covariance: $$COV(x,y) = \frac{\sum(x_i - \overline{X})(y_i - \overline{Y})}{n-1}$$

Correlation: $\frac{Covariance\ (X,Y)}{\sigma_x \sigma_Y}$

Where:

- x_i *and* y_i is the return of the asset X and Y
- $\bar{x}$ and $\bar{y}$ are the averages of the x_i and y_i in the sample
- n is the number of observations in our sample

Even if this method is quite simple to use, there is a major problem. Indeed, it does not allow taking into account the changes of correlation and volatility over time. There are a lot of articles that have proven that the correlation and the volatility are not stable through time[30]. So there is another naïve technique to solve this problem. It is presented here below.

B) <u>The rolling window volatility and correlation</u>

The historical or naïve volatility and the correlation can also be worked out on a more sophisticated way: the rolling window. The principle is that we take smaller samples of a determinate size to work out our values. When we are going forward in the sample, the oldest observation of the price is removed and the latest is added into the window. This technique allows taking into account the changes of volatility and correlation over time into account.

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[30] Ke-Li Xuy, "Powerful Tests for Structural Changes in Volatility", Texas A&M University, 2011.

The formulas used in the samples are the same as those presented in the previous section but with another sample that evolves over time.

The major disadvantage of those methods is that they are based on the assumption that what happened in the past will happen in the future too. To prevent this binding assumption, we have to introduce the principle of conditional volatility and conditional correlation.

2) *Conditional methods*

We now introduce an important part of our thesis: the principle of conditional volatility and conditional correlation. We begin with the conditional volatility.

The assumption of some conditional volatility models is that the values of the correlation or the volatility in time t can be worked out by the some values present in t-1 (The elements are the squared returns of the asset and the volatility in t-1. The values used depend on the model). So the conditional models permit to take the changes in volatility into account which is a more realistic assumption.[31]

There are a lot of conditional volatility models. The most known are the EWMA (Exponential weighed moving average) and the (G)ARCH model ((General)Autoregressive conditional Heteroskedasticity) of Bollerslev and Engle. We explain those models in the few next paragraphs.

A) EWMA

The easiest model is the EWMA model. The EWMA model uses two samples of data to work out the volatility for the time t: The volatility in t-1 and the squared returns in t-1.

[31] J. Hull, « Options, Futures and other derivatives », New Jersey, Pearson, 8th edition, 2011.

Here is the formula:

$$\sigma_t = \sqrt{\lambda \sigma_{t-1}^2 + (1-\lambda) u_{t-1}^2}$$

Where:

- σ_t is the conditional volatility on time t

- λ is a parameter

- $u_{t-1}^2$is the squared return of the asset on time t-1.

The value of the parameter λ must be comprised between 0 and 1. The λ parameter gives the level of sensitivity to new observations[32]. A λ near one means that the EWMA model takes slowly the new information given by the returns into account. Indeed, we consider that the u_{t-1}^2 term brings the new information about the changes of the volatility into the model. On the contrary a λ near zero means that the estimation of our volatility is very volatile. Usually a λ about 0.94 is used[33].

It is important to say that we can also use EWMA Model to work out the covariance[34]. In this case the formula is:

$$Covariance_t = \lambda \, Covariance_{t-1} + (1-\lambda) x_{t-1x} y_{t-1}.$$

Where x and y are the returns of the assets X and Y.

B) GARCH

The GARCH (p,q) models rely on the same principle but with one difference. They include a long term of variance (V_l) in the equation. The equation of a GARCH (1,1) is as follow.

$$\sigma_t = \sqrt{\gamma V_l + \alpha \sigma_{t-1}^2 + \beta u_{t-1}^2}$$

[32] J. Hull, « Options, Futures and other derivatives », New Jersey, Pearson, 8th edition, 2011.

[33] Ibidem

[34] Ibidem

We can assume that $\gamma V_l = \omega$ and the equation becomes:

$$\sigma_t = \sqrt{\omega + \alpha\sigma_{t-1}^2 + \beta u_{t-1}^2}$$

The parameters of the GARCH models are usually estimated by the Maximum Likelihood method. We do not develop this principle in this thesis.

The number in brackets (P, Q) after GARCH means the number of lags that you consider in your equation. Even if the (1, 1) model is the most popular, you can use (2, 2) (1, 2), (2, 1) models or other combinations. A (2, 2) model means that you take two lags of volatility and two lags of squared return in your equation. P means the number of lags of variance and Q the number of lags of returns.

There are a lot of different GARCH models: IGARCH, EGARCH which are all appropriate to work out the volatility when you have only one asset. They are called univariate GARCH models because they work out the volatility of only one asset.

But how to deal with several assets? A lot of research exist about this subject and we are going to shortly develop how to work with multivariate GARCH models because they include the principle of conditional correlation. This way, we develop the DCC (Dynamic Conditional Correlation) and the CCC (Constant Conditional Correlation) GARCH models to see the principles of conditional correlation as we did for the conditional volatility.

We speak about two of the multivariate GARCH models without detailing too much in our master thesis.

C) <u>CCC GARCH</u>

The Constant Conditional Correlation model was developed in 1990 by Bollerslev. The major advantage of this model is that it reduces the number of parameters to use. Before the CCC model, there were other multivariate GARCH models as BEKK or VEC models. The major disadvantage was that you had to use 52 parameters to estimate a model with 8 variables.[35]However even if the number of parameters is less important, there is a reductive hypothesis on which relies the CCC GARCH : we consider the correlation as a constant. We have to make a choice: either to estimate a lot of parameters or to consider constant correlation even if this is not true in reality.

This model allows to the conditional variance to vary over time. However the conditional correlation between the variables must be constant. This is an important constraint even if it simplifies the model.

This model is constructed by working out the individual conditional volatilities of the assets by a simple univariate GARCH model. All those values are used to construct a diagonal volatilities matrix which we call D_t.

Another Matrix R contains the structure of correlation between the assets. They remain fixed in this model because this is the assumption of the CCC model.

Finally we have to work out the variance covariance matrix H_t. It is obtained this way:

$$\begin{cases} H_t = D_t R D_t \\ D_t = diag(\sqrt{h_{11t}}, \sqrt{h_{22t}}, \cdots, \sqrt{h_{NNt}}) \\ R = \rho_{ij},\ \text{avec}\ \rho_{iit} = 1 \end{cases}$$

Source: « Modèles ARCH Multivariés », HEC Canada, <zonecours.hec.ca/documents/A2008-1-1503816.chapitre_14.pdf>, page accessed the 15th november 2012.

This variance covariance matrix must always be definite positive. If it is not the case, this matrix must become definite positive by calculations that we do not see in this thesis.

[35] « Modèles ARCH Multivariés », HEC Canada, <zonecours.hec.ca/documents/A2008-1-1503816.chapitre_14.pdf>, page accessed the 15th november 2012.

After that, we can obtain conditional covariance and the conditional correlation by the formula: $Correlation_{XY} = \frac{Covariance\ (X,Y)}{\sigma_x \sigma_Y}$. But the assumption of the CCC GARCH is that the correlation must be constant and we consider this constant correlation as an input. So this model does not help us for our project. It is why we decide to explain the DCC GARCH model because it uses conditional correlation.

D) <u>DCC GARCH</u>

We do not go into mathematical details or formula because it would take too much time and it could be the object of another complete master thesis. However we explain the major guidelines and principles to create a DCC GARCH model.

As for the CCC GARCH model, the individual univariate conditional volatilities have to be worked out by a univariate GARCH model for each asset. The difference between CCC and DCC is as follow: You have to consider a matrix of conditional correlation, R_t whose values are changing over time. This matrix contains the conditional correlation between the assets.

The DCC GARCH model is quite efficient and easier to use in comparison with other models according to the literature. Unfortunately there is no procedure to use it on SAS and we are unable to use it in our master thesis. We have tried to use a BEKK model but it did not work in our case. We will see which solution we use in our practical part.

d) Hedging Strategies

This part is dedicated to the theory about the hedging strategies. We first introduce the subject and our assumptions, after that we expose the hedges we develop to cover our commodity and our currency risks. We only explain the theory in this part. We will compare those strategies in our practical part.

1) *Introduction*

For our explanations, we make some assumptions and we always base the theory on this assumption: a client who has to buy a determined quantity of a commodity in few months (three in our case). So, to make a hedge, our client has to buy options, derivatives or futures to hedge his position; it is what we call long hedge[36].

As we are in the theoretical part of our work we only see the theory on those concepts and we give some examples too. We first speak about the commodity risk because we make more calculations to compare strategies among them. After the commodity risk, we propose a currency hedge to complete our total strategy.

2) *Commodity risk*

We have already seen in this thesis that there are two kinds of risk to take into account in our project: the commodity risk and the currency risk. We tried to gather all the information in this thesis about the hedge with futures (naïve and conditional hedge ratio) or hedging using options or other assets. It seems very important to us to make a summary of some different hedging techniques because the majority of the papers we have read study all those techniques separately. We explain the maximum of theory about those points.

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[36] J. Hull, « Options, Futures and other derivatives », New Jersey, Pearson, 8th edition, 2011.

As we said in our introduction, we make the assumption that our client has to buy some commodity in 3 months. We are going to develop the basis of hedging.

The principle of hedging is to reduce the risk of an investment. To do so we have to take an opposite position in another product which is strongly and positively correlated with our investment to avoid the risk. In our case, we have to buy derivatives to cover our position[37]. If we take the right quantity of covering asset (futures, option or other derivatives) we have no risk anymore because the variations of prices cancel each other. For example: if the price of commodity we have to buy increases it means that we have to pay more money than expected three months before. It is like a loss. To prevent this loss we should buy a determined quantity of derivatives and the variations of its price cancel the loss on the investment.

If we make a hedge there are two possibilities: the price of the Brent and the covering asset increase or decrease (they evolve together because they have to be strongly correlated). Whatever the possibility, we have no risk anymore if we have made a perfect hedge. If the price of the Brent increases, the loss is covered by the position in the covering asset (we sell the derivative we bought three months before at a higher price). If the price decreases, we have a loss due to our covering asset (we sell the derivative we bought three months before at a lower price). In the two cases we pay the price of the asset we have seen three months before. It is as if we had fixed the price. We give you another example in the following point of this thesis.

The plan of the next part is as follow: we begin with the hedging with futures, after that we also speak about the proxy hedging which uses derivatives on another underlying than the asset we want to hedge. Finally we create a hedge with options which is easier to explain and needs less explanation to be understood.

[37] W. Labys and C. Granger, « Speculation, Hedging and Commodity Price Forecast », Ed. Health Lexington Book, 1970.

A) Hedging with futures

The problematic of hedging with futures contracts is to determine the right quantity of futures contracts to buy to be perfectly hedged (it means a complete diminishing of the volatility). We can work out this quantity with the help of the Optimal Hedge Ratio (OHR*). We see in the following parts some different techniques to obtain our OHR: the naïve strategies and the GARCH strategies.

a) The naïve techniques:

We decide to expose two naïve ways to work out the hedge ratio which are presented in some articles or books of the literature: the first one is what we called the basic hedge ratio and the second one is the rolling window hedge ratio. As for the correlation, the naïve approach relies on the principle that the correlation of the past will be the same in the future.

- Basic hedge ratio:

We first consider that the optimal hedge ratio between the futures contracts and the Brent oil price is equal to one. We call this technique the Basic Naïve approach. The principle is as follow: as a futures contract is a contract on a commodity, a basic approach could be to expect that the correlation between the price of the futures contracts and the spot price is always equal to one. So the variations in prices must be the same because the underlying of the futures contract is the commodity. Please retain this because it is really important in the following paragraphs.

So, in this case: $OHR = 1$

Explanation: when you use this basic hedge ratio, you have to buy (or sell) a quantity of futures contracts which correspond exactly to the quantity of the commodity you will have to buy (or sell) in the future. You also have to take contracts with a little bit more maturity than the date of your deal except if you want to be delivered but we do not consider this alternative. In an oil hedge, this technique is also called barrel to barrel hedge.

So the number of contracts to buy (or sell, it depends on the position you want to hedge) is as follow:

$$Number\ of\ contracts = \frac{quantity\ of\ commodity\ to\ hedge}{quantity\ of\ commodity\ per\ futures\ contract}$$

For example, if you have to buy 3000 tons of iron in 3 months and if each futures contract involves 1000 tons of iron, you have to buy 3 futures contracts with a maturity of at least 4 months to cover your position. When your purchase (or sale) happens, you sell (or buy) your futures contracts. The contract can be sold (or bought) because it remains a maturity of one month.

The result of the hedging strategy is as follow

$$Spot\ price\ variation\ during\ the\ hedge = S_{t=3m} - S_{t0}$$

$$futures\ contract\ price\ variation = Futures\ price\ _{t=3m} - Futures\ price\ _{t0}$$

Where:

- S_{t0}: the spot price per iron unit when you decide to buy (t=0).
- $S_{t=3m}$: the spot price of the iron unit 3 months after
- $Futures\ price_{t0}$: the price of the futures contract in t=0 (maturity =4 months)
- $Futures\ price_{t=3m}$: the price of the futures 3 months later. (Maturity = 1 month)

If our hypothesis of the same variations of prices is correct, the final price that you pay is as follow:

$$Price\ actually\ paid_{t=3m} = S_{t=3m} - price\ variation\ of\ the\ futures\ contracts$$

If our hypothesis is correct (correlation equal to 1) this price is equal to $S_{t=0}$. You pay the price which was in place 3 months earlier because the variations of the spot price are cancelled by your position in futures. The hedge works perfectly. The loss due to the increase of the spot price is compensated by the profit generated by the position in futures contracts (in the case of a long hedge).

But you do not have to forget that we take the hypothesis that the variations of prices between our futures contracts and the commodity price are the same (correlation equal to one). But this is not correct in the real world. The correlation between the spot price and the futures varies over time and with the maturity of the contracts we use: this is the Samuelson Effect[38]. A consequence of this effect is that the correlation between the spot price and the futures price decreases when the maturity of the contract increases[39], so this correlation varies through time and that breaks our hypothesis of constant correlation.

But to solve this problem of moving correlation over time, we propose another strategy which works out the OHR with more sophisticated calculations.

- The rolling window technique:

The rolling window technique uses rolling window standard deviation and rolling window correlation to work out the hedge ratio. It is advised to use a window with a width which corresponds to the maturity of the hedge. For example if you want to hedge your position for 3 months, you can use a 3 month window, but you are not obliged to do this.

When you have worked out your standard deviations and the correlation between ΔS and ΔF by following the historical approach, you can apply this formula given by J. Hull in Options, futures and other derivatives:

$$h^* = \rho \frac{\sigma_S}{\sigma_F}$$

[38] See the part about the term structure of futures prices for more information

[39] D. Lautier and Y.Simon, “La volatilité des matières premières”, Cahier de recherche du CEREG n°2003-15, Université Paris Dauphine, 2003

Where:

-ΔS is the spot price variation in the hedge period (the returns are also used)

-ΔF is the futures price variation during the hedge period (the returns are also used)

-h* is the Optimal hedge ratio

-ρ is the correlation between ΔS and ΔF

-σ_S is the standard deviation of ΔS

-σ_F is the standard deviation of ΔF

After the calculations of the OHR*, we use it to work out the right quantity of futures contracts to purchase by using this formula which is also given by J. Hull:

$$N^* = \frac{h^* V_A}{V_F}$$

Where:

-N^* is the optimal number of contracts to buy

-h* is the Optimal hedge ratio

-$V_A$is the value of the position to cover. The position is the quantity to hedge multiplied by the unit spot price.

-V_F is the monetary value of one futures contract (the quantity of commodity covered by one contract multiplied by the futures unit price)

It is important to say that in this case we work with the positions to hedge (the quantity multiplied by the unit price). It is different from the basic naïve hedge because we considered before that a quantity of a commodity in the future corresponded to a quantity of commodity today. In this case we work the optimal number of contracts with the positions in futures and in spot barrels (and no the quantity) to take the daily clearing into account[40].

For example, we have to hedge 1000 barrels, the spot price is equal to 60$, the futures price is equal to 65$ and each futures contract is over one barrel. We have also obtained a hedge ratio of h*=1.2 with the correlation and the volatilities. To obtain the number of futures contracts to buy (N*), we have to multiply this hedge ratio by the

[40] J. Hull, « Options, Futures and other derivatives », New Jersey, Pearson, 8th edition, 2011.

quantity of barrel to hedge, the spot price and to divide it by the value of one futures contract. And so:

$$N^* = 1.2 * \frac{(1000*60)}{65*1} = 1107.$$

b) The GARCH techniques

We have to find a solution to avoid the hypothesis of the naïve approach. To do so it is also possible to work out the OHR with the conditional values. As we have seen earlier in this master thesis, it is possible to obtain conditional correlation and conditional volatility with the GARCH models. The calculations for the OHR are the same, the changes are only about the calculations for the correlation and the volatilities.

The advantage of those techniques is that we do not rely on a naïve hypothesis anymore. We can work out the correlation during our hedging period and not during the previous one. However the efficiency of the GARCH OHR decreases when the length of the hedge increases. In other words a GARCH OHR performs better for a hedge on the short terms than for a hedge on the long term.[41]

c) The rollover strategies

The previous strategies relied on the principle of a unique hedge for the whole period we want a protection. But there are other possible dynamic techniques which need more transactions. One of those techniques is called the rollover strategy.

The rollover is used to avoid two problems: firstly, the correlation between spot prices and futures prices decreases when you use contracts with a longer maturity (because of the Samuelson effect); secondly, the problem of liquidity of the contracts decreases with the increase of the maturity too. But why does the liquidity play a role in the effectiveness of a hedge?

[41] J.Cotter and J, Hanly, “Reevaluating Hedging Performance”, the journal of future markets vol.26, 2006.

We have read in the literature that as for the correlation, the liquidity of the contracts decreases when the maturity of the contract increases.[42] But the diminishing of liquidity depends also on the commodity. There are some markets as the oil market where the liquidity is quite important even if the maturity is important but it is not the case for all the other markets. So the hedgers have created the rollover strategy to solve the problem of a lack of liquidity.

The principle of the rollover strategy is to buy the nearest month futures plus one month and to sell this contract one month later. We have to repeat this operation each month we want to continue our hedge.[43]Each month our operation gives us what we call "a roll" the same way as what happens for the basic naïve hedge. The difference is that at the end of the hedge, the sum of the rolls is equal or quite similar to the variation of the spot price during our hedge period. We need several operations to obtain this amount. The OHR of each month can be worked out by the previous techniques (basic naïve hedge, rolling window OHR or GARCH OHR). But this technique involves some disadvantages. We see them together.

This strategy is quite efficient to have a relatively efficient hedge but it needs more transaction costs than a normal or "naïve hedge" because, and it is not difficult to understand, it needs more transactions (at least 1 per month during the lifecycle of the hedge).

Another limit is that this technique is quite dangerous and costs more money when the futures curve is in a strong Contango shape (see below). The company Metallgesellschaft lose more than one billion dollar because they did not take this shape into account.[44]We explain why later.

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[42] D. Lautier and Y.Simon, "La volatilité des matières premières", Cahier de recherche du CEREG n°2003-15, Université Paris Dauphine, 2003

[43] J. Hull, « Options, Futures and other derivatives », New Jersey, Pearson, 8th edition, 2011.

[44] C Culp and M Miller, « Corporate hedging in theory and practice, lessons from Metallgesellschaft", Ed. Riskbook, 1999.

d) Proxy hedge

The principle of the Proxy hedge is to use futures or forward contracts on another underlying than the asset we want to cover. This principle is really useful when there is no derivative for the assets you want to hedge or when the derivatives are not liquid enough.

The calculations are exactly the same but with other products. The difficulty is to find another asset which has a strong correlation with your investment. Proxy hedge is often used for the currencies.

That kind of hedge is not really relevant in our case because there are very liquid futures contracts on the Brent oil. Therefore we do not use this strategy in our practical part because it is never used in a hedge on oil.

B) Hedge using options

The options give other possibilities to make hedging strategies. We do not insist on them because we would rather insist on the futures and forward contracts. However we use them to make a comparison between the use of futures and the use of options.

We also consider the situation of a company which has to hedge a buy of commodity in the future. To make a hedge, the company has to buy call option. The number of options to buy must correspond to the quantity of asset to hedge. We develop the different possibilities: the prices have decreased and the prices have increased.

Decrease: Your hedge is useless but the situation is good for you. You can normally buy your asset at a lower price than at the moment you have decided to buy; you do not have to exercise your right. The value of your option is equal to zero and the cost of your hedge policy is equal to the price at which you bought the options. In this situation, the final result is equal to the price diminishing minus the option premium paid

Increase: Your hedge is useful. Your call option value has increased and you have the right to buy the asset at the strike price. At this time, you have two possibilities: you exercise your right and you buy the asset, or you sell your option before maturity and the benefit of this sale compensates the increase of the price of the commodity. The benefit of your hedge is: you win the increase of the price minus the price of your option.

The differences between option and futures hedges are the following ones (for a long hedge):

-With futures hedges you fix the prices: it is positive when the prices increase and negative when they decrease. In case of option hedge, you are only hedged for price increase and you could still take benefits from a decrease in price.

-Option hedging is more costly than futures hedges because options are like insurance. The risk you take with futures contracts (you are not able to take profits from a decrease of the commodity price) explains why it is cheaper.

3) *Currency risk*

The hedge for the currency risk can also be achieved with the previous products (futures, options, proxy...) but the bank in which we made our internship usually uses forward contracts. We take the opportunity to explain hedging with forward contracts to avoid the currency risk.

When a company has to buy some asset or commodity into another currency, there is a currency risk. It means that the company is exposed to an increase of the cost only by the decrease of the exchange rate. For example, if European company has to buy 1000 dollar of a commodity and if the value of the Euro Dollar exchange rate is equal to 1.5, the company has to pay 1000$/1.5= 666.67€. But if the exchange rate decreases, for example 1.4 $ per euro, the company would have to pay 1000$/1.4=714 €. There is a difference of 47.6€ only because of this exchange rate, with no change in the commodity price.

A drop in the exchange rate can quickly lead to a significant loss for a company in the case of importations. It is the same for exportations in the case of an increase. The principle of forward contracts in quite similar to the use of futures even if we do not make different calculations in this case. We only use the "normal" forward contract hedging: we buy a contract on the quantity of dollar we will have to pay to buy our oil.

The other important thing to know about forward contracts and which is different from futures is that there are no standardized contracts. The counterparties have to well identify their needs before buying a contract.

We now explain some terms which are relative to the currency market like deport and report in the case of a buy of forward contract.

The report happens when the forward rate is higher than the spot rate (the basis is positive)[45]. Analysts expect an increase of the exchange rate. This difference is like a cost for the buyer because he would not have to pay this difference if he had bought the currency on the spot market and had waited to do his operation[46]. So this difference is the cost of buying forward. However, there is an advantage to buy forward: the company does not have any disbursement in its treasury during the operation and this money can be used for other things. You must make a compromise between the payment of the basis and the disbursement in your treasury.[47]

The deport is the opposite (the basis is negative). This is when the forward rate is lower than the spot price. In this case the basis is a profit for the forward buyer. He receives this basis because the analysts think that the exchange rate will fall.[48]

When you have bought a forward contract, you are protected against the variation of the exchange rates. There are two situations as for hedging with futures contracts. In the case of buying of forward, you have profits if the exchange rate falls and losses if the exchange rate goes up.

[45] J. Peyrard, « Les marchés des changes : opérations et couvertures », gestion Internationale, ed. Vuibert, Paris, 1995
[46] Ibidem
[47] Ibidem
[48] Ibidem

We now see how to work out the forward exchange rate. Bloomerg gives the point to add to or to subtract from the spot exchange rate to have the forward exchange rate in the case of a sell or a buy of forward contract. For example, we have those data about the three month forward:

Table n°03: Forward points

Date	3 month Forward	6 month Forward	Spot rate
10/08/2006	70,22	132,93	1,2773
11/08/2006	70,5	132,95	1,2732
14/08/2006	70,56	133,28	1,2736
15/08/2006	70,42	134,2	1,2785
16/08/2006	71,4	132,04	1,2854
17/08/2006	69,68	130,33	1,2842
18/08/2006	69,53	129,83	1,2809
21/08/2006	70,53	130,65	1,2906
22/08/2006	69,3	131,48	1,2804
23/08/2006	70,75	130,9	1,2783

Source: excel, data from Bloomberg

This table n°03 is the quotation in point given by Bloomberg for 3 and 6 months forward buy of dollar in euro by an investor (so a sell for the bank). We can find two major pieces of information:

-The market is in report because the points are positive (the basis is positive).

- The 16/08/2006, the value of the forward exchange rate is 71.4/10000+ spot rate (1.2854). If you buy a 3 month forward, we have to divide the point in 10 000 because the exchange rates are quoted with 4 decimal places[49]. So, in our case, the investor who buys the forward contract has fixed his exchange rate to 1.2854 + (71.4/10000) = 1.2925. He will be able to buy the determined quantity of dollar with the contract for 1.2925 $/€ in three months. He will have a benefit from his hedge if the exchange rate is lower than this value and a loss if it is higher than this value.

[49]J. Peyrard, « Les marchés des changes : opérations et couvertures », gestion Internationale, ed. Vuibert, Paris, 1995

e) Term structure of futures prices

Another aspect that we have to take into account for the implementation of a hedging strategy is the term structure of the futures prices. Indeed, as we have quickly seen previously, the volatility of the futures prices and also the correlation with the spot price are changing with the maturity of the futures contract; this is the Samuelson effect. We now see how this principle is relevant in our thesis.

We first explain the term structure of futures prices. Then we explain the volatility of this term structure. After that we explain how to measure the differences between the term structure curves. Then we explain the principles of Contango and Backwardation and we finish with the link with our thesis by giving the example of the Metallgesellschaft, a company which did not take this principle into account and lost more than one billion dollar.

1) *Explanation of term structure of futures prices*

First it is important to explain what we are talking about. That is why we choose a simple definition of the term structure of the futures prices which is given by Delphine Lautier:"*The term structure of futures prices describes the relationship between the spot price and futures prices for different delivery dates".* A term structure exists when an asset is quoted for different delivery dates. There is so a relationship between futures prices and spot prices. And even if there is a link between spot and futures prices, the link is not exactly the same through time. There is so a determined difference between the prices for each different maturity in time. And, in general, this difference, also called the basis, increases with the maturity of the futures contract. Thus, in general, the nearest the maturity of the futures contracts, the smallest is the basis because the futures prices must be the same than the spot price at maturity.

This relationship between spot prices and futures prices can be expressed by the following formula:

$$F_0 = S_0 e^{cT}$$

Where:

-F_0: is the price of a futures contract with a maturity T today.

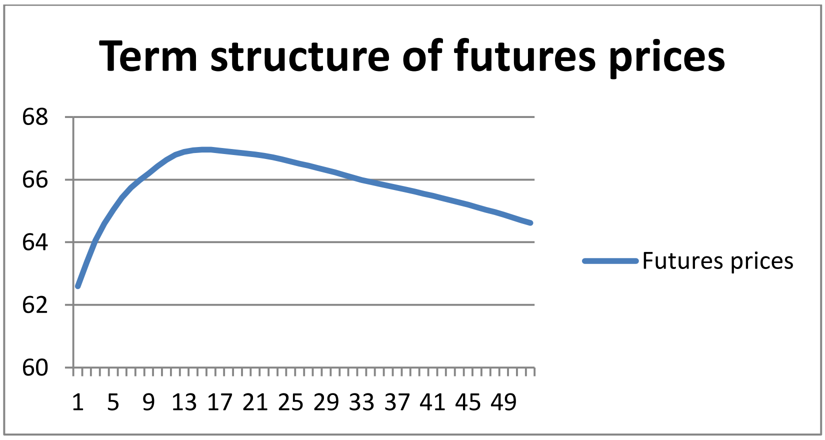
-S_0= the spot price of the underlying today.

-c is the discount rate. This rate is composed of the interest rate, the storing cost and the convenience yield. We discuss the different components later in this part.

-T is the maturity of the contract in years.

Figure n°1 is an example of a real term structure of the Brent oil futures prices. It is a screenshot of the situation on the 26 February 2006. The x axis represents the maturity of the contracts (1 to 52 months) and the y axis represents the prices in Dollar. This graph shows the prices for futures on the Brent oil with different maturities. All the data are downloaded from Bloomberg and we make our graph with Excel.

Figure n°01: Term structure of futures prices



Source: Excel, Data from Bloomberg

2) *The volatility term structure*

Now that we have defined the term structure as relationships between futures and spot prices, we explain the volatility of the term structure. To do this we explain the Samuelson's effect.

According to Samuelson, the volatility of the futures prices decreases when the maturity increases. So the prices of the futures contracts with short maturities vary more than the prices of the futures contracts with longer maturities. So there exists a difference of volatility between those contracts. This is what we call the segmentation of the term structures of futures prices.[50]We can make a distinction between the two ends of the futures prices curve: the left end (short maturities) which has a lot of volatility and the right end (long maturities) which has lower volatility.

This difference of volatility is explained by the fact that the contracts with a shorter maturity react faster to new information[51]. On the contrary, the contracts with longer maturity do not react to "short term changes" but react to long terms changes.

Delphine Lautier has studied those differences of impacts between different crude oil futures prices. For the short term, the contracts react to the production level, the consumption, the level of the stocks and the fear of a shortage in the supply of the commodity. Indeed, all those variables bring information on the demand-supply relation. It is why those variables are called *informational shock*[52].

For the long term contracts, the variables which have an influence are quite different: interest rates, inflation and the prices of other energies.[53]In other words: the variables which have an impact on the long term price. Delphine Lautier has also seen that the long term futures contracts do not react to the informational shocks as much as the short term contracts. However the long terms variables influence the

[50] D. Lautier and Y.Simon, "La volatilité des matières premières", Cahier de recherche du CEREG n°2003-15, Université Paris Dauphine, 2003
[51] ibidem
[52] ibidem
[53] Ibidem

contracts with short maturities too[54]. It is why there is a difference between the two ends of the term structure curves in term of volatility.

We have seen that there are important differences between different futures prices curves of the same underlying asset at different moments. We will see different techniques to measure those differences between different curves in the following part.

3) *Measures of the differences between the term structure curves*

A) Explanation

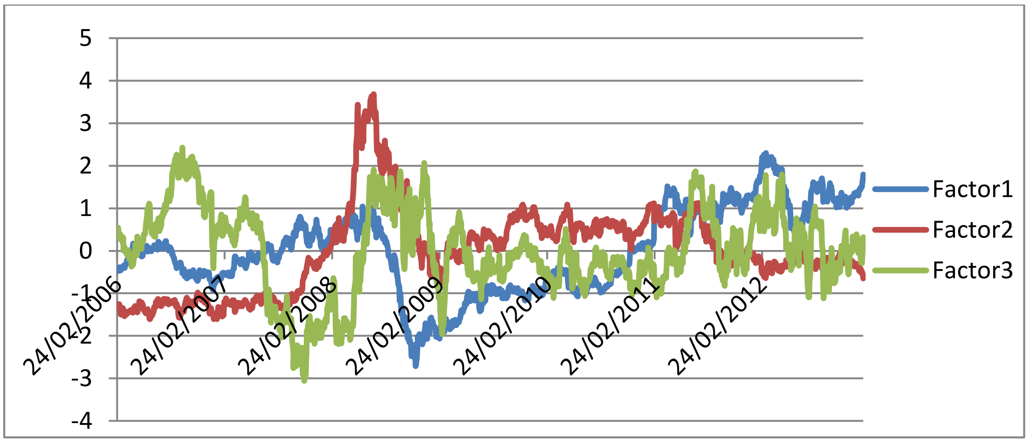
It seems important to determine the differences between the term structure curves for the same asset. To do this, we use a method we explained earlier in this thesis: the Principal Component Analysis. This PCA resumes an important number of variables into a smaller number of orthogonal variables called factors.

It is known in the literature that PCA can effectively resume the term structure of the futures prices. The PCA resumes the futures prices of different maturities into three main factors. Usually those three factors are enough to explain an important part of the variance of the total sample.

We do this Principal Component Analysis to give you an example with our own data we downloaded from Bloomberg. We use the prices of the futures contracts on the Brent oil with maturities from 1 to 52 months. We take the daily data and we select the contracts which are liquid enough to be included in our analysis. After that we use the Procedure FACTOR on SAS and we obtain the daily value of our three factors which resume all the prices of the liquid contracts. Those values are the daily values of each factor and so we can represent them on the next chart we obtain with Excel on the figure n°02

[54] D.Lautier, "The term structure of crude oil futures prices: a principal component analysis"; Cahier de recherche du CEREG n°2004-02, Université Paris Dauphine, 2004

Figure n°02: PCA factors



Source: SAS and Excel, Data from Bloomberg

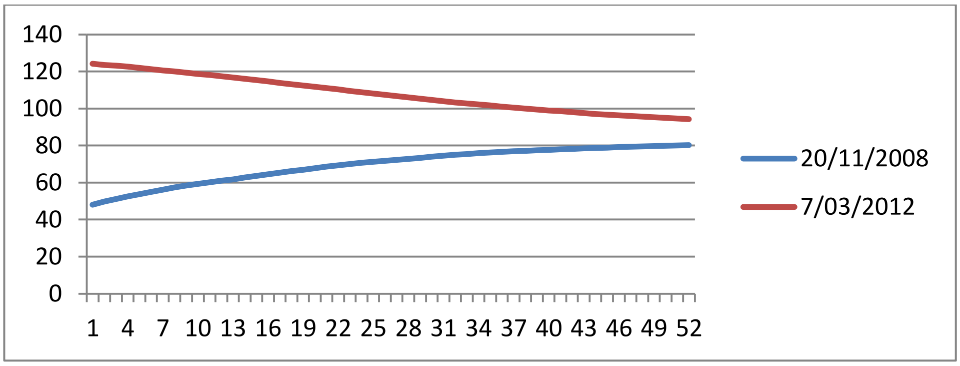
B) Signification of the factors:

We now explain the signification of those factors in details:

a) Factor 1: the level of the prices

On the figure n°03, there are two curves of the futures prices with an important difference in what concerns the value of the factor1. This first difference is the level of the prices. It means that all the futures prices are high or low following the value of the factor. On our example, a weak factor1 on the 20/11/2008 means that all the futures prices are low in comparison to a strong factor1 on the 7/03/2012 (all the prices are high). In conclusion, a strong factor 1 means high prices for all the maturities and inversely.

Figure n°03: Contango and Backwardation



Source: Excel, Data from Bloomberg

This factor 1 indicates a change on the entire curve (for all the maturities), so changes in variables which influence the entire curve (short and long maturities). We have seen previously that those variables are among others: interest rates, inflation and the prices of other energies in the case of oil.

b) Factor 2: the slope of the term structure curve

To illustrate this factor we use the same curves of the figure n°03. The factor 2 is positive for the blue curve and negative for the red curve. And we can also see that the blue one has a positive slope and the red one has a negative slope. This is the interpretation of the factor 2.

How can that happen? We have seen earlier in this thesis that some variables could only affect the contracts with short maturity; we called those variables "informational shocks". Indeed, new information about the demand/supply equilibrium has a more important impact on the left end of the curve (short term). It explains the difference of slopes. Indeed, new information about a lack of supply will lead to quick increase of the prices and new information about a good supply will lead to a fall of the prices in the short term. In conclusion a positive factor 2 means a positive slope and inversely.

A positive slope is also called Contango situation and a negative slope is called Normal Backwardation. We see those principles in a following part because it is really important in the implementation of our hedging strategy.

c) Factor 3: the curvature

This factor is the less representative. However we can take the same curves to illustrate it. A positive value of the factor 3 means a convex curve and a negative factor 3 means a concave curve. However this factor is not so important to explain the variance of the sample because it is the last one extracted by PCA.

In conclusion we can say that there are three differences between the term structure curves: the level, the slope and the curvature. In the next part we will see some formula to explain the two kinds of situation that can happen in the futures market: Contango and Backwardation.

4) Contango and backwardation

Now that we have well defined the possible differences between the term structure curves, we insist on the principle of Contango and Backwardation but using another way to explain by using the convenience yield. We explain those principles because they represent the two situations that can happen on the futures market. Moreover we use them intensively in our practical part. We first explain the Contango principle and we finish with Backwardation.

A) Contango

We begin with the Contango situation because it is the more usual. Contango means that the futures price curve has a positive slope and it is the most common situation[55]. We have seen that a positive slope means a positive factor 2 with our PCA. But there is another approach to understand. We explain this with the formula we have seen previously in which we add other details.

$$F_0 = S_0 e^{(r+u-y)T}$$

Where:

-F_0: is the price of a futures contract with a maturity T Today.

-S_0= the spot price of the underlying today.

-r is the riskfree rate

-u is the cost of storage (in percentage of the price of the asset to store)

-y is the convenience yield

-T is the maturity of the contract in years.

The convenience yield can be defined as "*the flow of services that accrues from possession a physical inventory but no to the owner of a contract for future*

[55] Javier Blas, "Brent's futures flip rolls up profits for crude investors", the financial times, 27th February 2013.

delivery"[56]. This is the benefit to have the asset instead of buying it thanks to a forward or futures contract. For example, in the case of a shortage of oil on the market, the owner of a determined quantity of oil has some benefits from this situation. Indeed, the value of his oil increases because there is no oil enough on the market. Moreover he could use his oil while the other oil consumers have to wait for the restoring of the supply. This convenience yield is the benefit to own the asset.

We can work out this convenience yield thanks to the formula above. But some research has been done about this yield. We do not develop them in this thesis but if you are interested, we invite you to consult the papers of Brennan (1987) or of Gibson and Schwartz (1990) about other ways to determine the convenience yield.

As far as Contango is concerned, the futures price is always higher than the spot price. It means that (r+u-y) is positive. So the convenience yield y is smaller than the riskfree rate plus the cost of storage. The exponent is positive and so the positive slope is normal because the maturity increases from left to right on the x axis. The interpretation of this positive slope is that the effects of the interest rates and the storing costs are included in the futures prices. As those costs increase with the time, it is normal that the futures prices are higher than the spot price because they are included in the futures price.

B) <u>Backwardation</u>

A backwardation-situation futures prices curve means that the slope is negative. But there is another signification for this term. We have to take our formula again[57]:

$$F_0 = S_0 e^{(r+u-y)T}$$

It means that the convenience yield y is higher than the cost of storage plus the riskfree rate. We have seen before that the slope of the futures prices can only be

[56] D.Lautier, "The term structure of crude oil futures prices: a principal component analysis"; Cahier de recherche du CEREG n°2004-02, Université Paris Dauphine, 2004

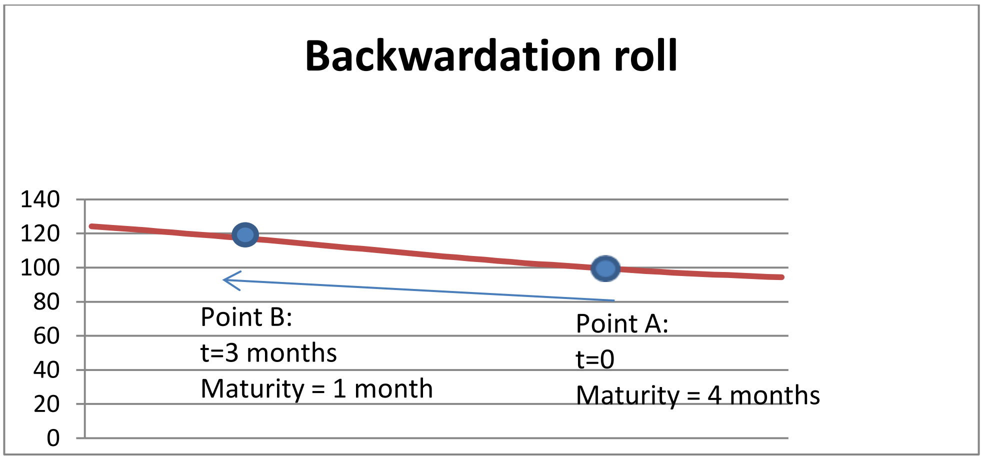
[57] J. Hull, « Options, Futures and other derivatives », New Jersey, Pearson, 8th edition, 2011.

influenced by informational shocks like a disturbance of the supply, a shortage in the stocks, short term events (war, hurricane…) and so on. So a backwardated situation happens when there is a strong informational shock. Investors want to buy the asset on short term to be sure to own it instead of buying it with long term futures contracts. It is why the contracts with short maturities worth more than the contracts with long maturity and the downward sloping of the term structure curve.

As the convenience yield is more important, the exponent (r+u-y) becomes negative. And as the maturity increases from left to right, it is normal to have a negative curve. The yield which is associated with the owning of the asset is bigger than the cost of storage, transactions costs and so on. Consumers want the asset.[58]

Backwardation situation are quite rare (except on the oil market[59]) and the traders are really fan of them because it means a roll benefit if there is no change in the level of prices which is not possible on a Contango market. During Backwardation, they can buy a futures contract and they take benefit from this position only by waiting because the futures prices increase over time. This is not the case on Contango market. There is an example on the figure n°04. We make this graph with data from bloomberg.

Figure n°04: backwardation roll



Source: Excel, Data from Bloomberg

[58] B Latendorf, "Spot Market strength is driving curve", financial times, 5th march 2013
[59] Javier Blas, "Brent's futures flip rolls up profits for crude investors", the financial times, 27th February 2013.

This graph represents the futures term structure at a defined moment. The Y axis represents the prices and the X axis represents the maturity of the contracts. In our example a trader buys a determined quantity of futures contracts with a maturity of 4 months in t=0 (point A). If we suppose no change in the level of the prices, the curve stays the same through time. So our trader could sell the same quantity of futures 3 months later (point B) at a higher price only because of the slope of the curve. This is the benefit from the roll and it is equal to price in B minus the price in A. This gain is also called backwardation gain.[60] This roll is negative in case of Contango market because the slope is inverted.

C) *Link with hedging strategies*

The term structure of futures prices does not seem to be a topic relative to the hedging strategies. But in fact it is terribly important. We will explain why with the example of the Metallgesellshaft Company.

This German century-olded company had a lot of activities in the trading, engineering and other financial services[61]. One of its marketing objectives was to offer a price guarantee to its clients. This guarantee was over the oil price.

To reach this objective, the company implemented a hedging strategy using a rollover strategy like we have seen together: the Metallgesellshaft transforms a long term hedging into a following of short term hedging. This strategy was attractive because the oil market is usually downward sloping (this is an exception on the commodity market.)[62]and, as we saw before, the roll of this strategy gives a profit in case of a stable and backwardation-situation market.

With this strategy, the company had two advantages: an incredible marketing advantage and a profitable, self-financing hedging policy thanks to this roll. This was, at first sight, the paradise of hedging and the Metallgesellschaft used intensively this rollover strategy.

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[60]C Culp and M Miller, « Corporate hedging in theory and practice, lessons from Metallgesellschaft", Ed. Riskbook, 1999.
[61] Ibidem
[62] Ibidem

However, an unexpected fail in the fuel production-quotas agreement by the OPEC appeared. This event led to an important fall in the prices in the short term (an informational shock). This shock transformed the market from a backwardation-situation to a contango-situation. The rolls which were expected to be positive became negative because of the contango-situation.

Those negative rolls and the important fall of the oil prices led to a huge loss for the Metallgesellshaft. The company was not able to pay the margin call asked by the clearing house. This situation led to a loss of 1.08 billion dollar[63]. The Metallgesellschaft thought that it was not possible for the backwardation-situation oil market to become so fast a contango-situation market. They did not take the possibility of informational shocks into account. It is why the term structure of futures price is really important in our project.

[63] ibidem

IV. Practical Part

Our practical part is divided in three steps: the period of correlation identification, the comparison of hedging strategies (commodity and currency) and a simulation on the selected strategy on which we apply the currency hedge.

We use the theoretical elements we have explained in the previous part to explain how we obtain the results of our practical part. We do not come back to the theoretical elements and we also put some elements in appendix to be as clear as possible. Now we are going to divide our sample into different correlation periods.

a) Presentation of the selected sample

We now explain the sample of data on which we do our three steps. We take a sample which begins the 24 February 2006 and finishes the 1 February 2013 because all our data are available between those dates. Now we describe the main values we select. All our calculations in the practical part use this sample of values. However some charts use a wider sample because the data are available.

We decide to use the ICE Brent Index as the crude oil spot price. This is a weighted average of the nearest months futures quoted on several markets. Indeed there is not an official unique showed price for this commodity. We find that using this index is really relevant. When we speak about "Crude oil spot price" or "Brent price" later in this thesis we actually mean this index price. More information about the calculation of this index is available on the ICE website[64].

For the Euro Dollar exchange rate, we download the full daily historical data from Bloomberg as for the Brent index.

[64] ICE intercontinental Exchange, calculation of the Brent index, <https://www.theice.com/publicdocs/futures/ICE_Futures_Europe_Brent_Index.pdf>, pdf online, page accessed the 5th April 2013

We convert the Brent Price and the Exchange rate value in weekly data by taking the Friday's values thanks to the "Vlookup" function in Excel. We do this transformation into weekly data to have smoother curves and also because daily data brings us too much information and it is useless in our case.

For the futures prices we download the prices from Bloomberg. We also transform the daily data into weekly data. We have taken futures with maturities from 1 to 52 months. We use those prices in our part about the hedging strategies.

b) First step: identification of periods

1) *Objective*

The objective of this part is to detect on which risk we have to make a hedge. This is the first step of our practical part. To reach this objective, we develop an indicator which uses the correlation between the Euro Dollar exchange rate and the Brent oil price. Indeed we have seen that the correlation in really important to identify the hedging strategy.

To do this, we first study the differences of correlation between the Euro Dollar exchange rate and the Brent Oil price and the possible impacts on the hedging strategy. After that we will analyze different categories of variables which could have an impact on this correlation. We will finish this part by testing our indicator on the Brent oil price. All the data are available in the excel file called "Periods_Benjamin_Brine.xls" on the attached CD.

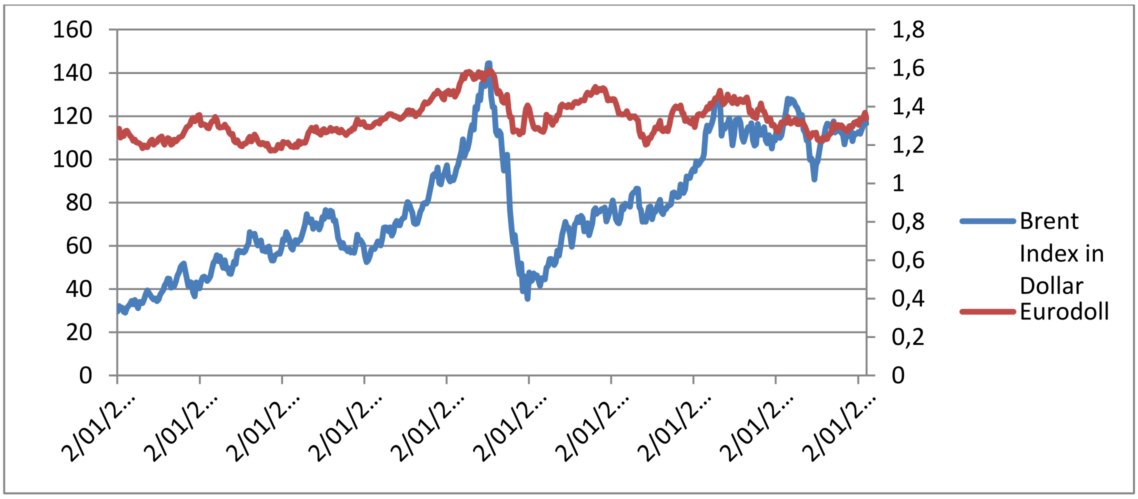
2) *Correlation analysis*

A) Introduction

It is important to know that we use the correlation between the prices and the exchange rate. We do not take the returns because we want to take the levels of the prices into account. We also made the analysis with the returns but it seems impossible to determine different periods on an effective way. You can see the chart on which we made our analysis in appendix n°004. We do not insist on this point but we know that it is infrequent to use the prices instead of the returns but the results are better in our case.

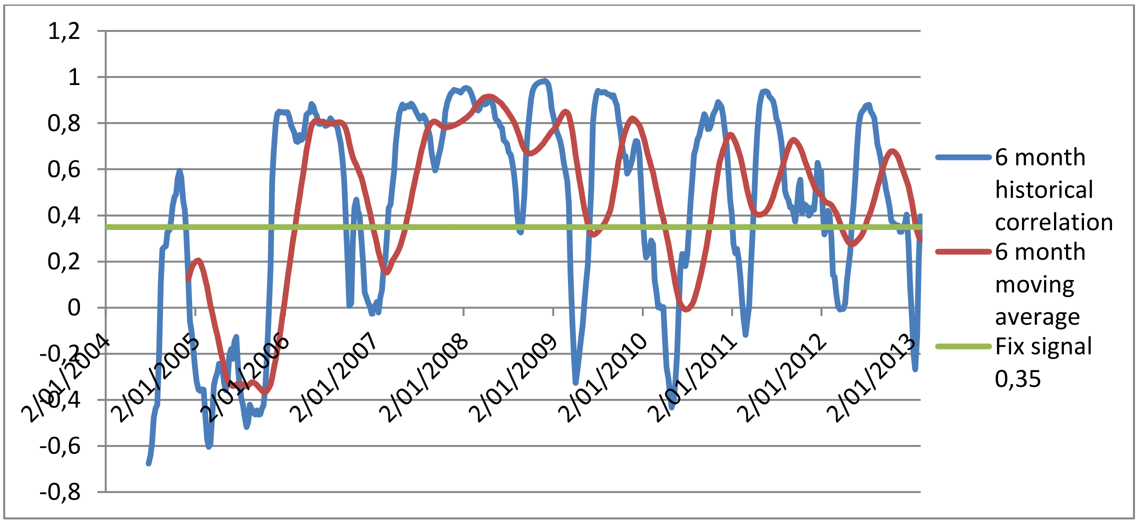
On the following graphs, you can see that there is a common trend between Brent price in Dollar en the Euro Dollar exchange rate. Figure n°5 shows the evolution of the prices. Figure n°6 shows the rolling historical correlation on the Brent price in Dollar and the exchange rate with a window of 6 months.

Figure n°05: Eurodoll and Brent price



Source: Excel, Data from Bloomberg

Figure n°06: Historical correlation and signals



Source: Excel, Data from Bloomberg

As you can see, the historical correlation is in general quite important (superior to 0.6), but there are also “gaps” in correlation in which it decreases below the 0.35. We will analyze the differences between a situation with high correlation (superior to 0.35) and weak correlation (less than 0.35) in the next part of this thesis. We select a 0.35 limit because it is the value of the historical correlation between the Brent in Dollar Price and the Euro doll of our sample (0.36973). When the 6 months correlation crosses down the 0.35 limit, we consider that as a signal of low correlation period.

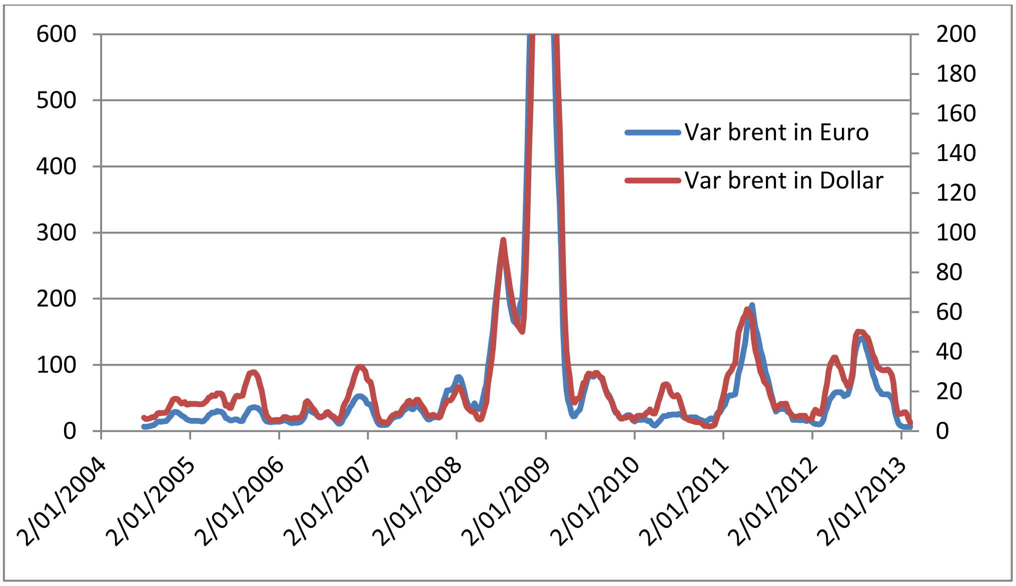
We also use a six months moving average to determine the samples in which the correlation is weak. When the historical correlation crosses the moving average, we consider that as a signal in the same way as we did for the static 0.35 limit. As you can see on the graph the periods are quite the same with only few exceptions and we consider that those two signals are the same. We use the moving average indicator for our hedging strategy later in this thesis because this is a dynamic indicator which gives more signals and it is more appropriate to take quickly the smaller gaps of correlation into account. Those analyses of correlations could help us to decide if we have to hedge us against a currency or a commodity risk.

B) Results and observations

First we observe on the figure n°7that the periods of low correlation correspond to a difference between the variance of the Brent oil price in Dollar and the variance of the Brent oil price in Euro. A difference between those variances comes only from a change in the exchange rate. Indeed, this is the only one difference between the two variances of prices. As you can see, it seems that those differences happen when the correlation between the exchange rate and the Brent in dollar is weak and is so detected by our indicator. It is why we decide to analyze those results in detail. We also observe that the variance comes mainly from the commodity and not from the currency.

Here is the graph on which we make our observations. The left Y axis is for the variance of the Brent in dollar and the right one is for the variance of the Brent in euro.

Figure n°07: Brent variances



Source Excel, Data from Bloomberg

Even if the variances do not have the same scale, we can see that the variance of the Brent in euro increases more than the variance of the Brent in dollar at different moments in time and those moments correspond to the gaps of correlation. So, a weak correlation means a more important increase of the variance in Euro than the variance in Dollar. Those increases of correlations are due to changes in the exchange rate because this is the only difference between the Brent in Euro and the Brent in Dollar. It means that the currency risk increases and so a currency hedge could be needed. We are going to see the causes of those changes of correlation.

C) Determination of the samples to study

As we have said before, we decide to analyze gaps of correlation because they could indicate if we have to add a currency hedge to our commodity hedge. Those changes could result in a disequilibrium between some important classes of variables (see next part). We study samples with "normal" correlation to be able to compare the two situations. In our case "normal" correlation means high correlation because you can see in the literature that the Euro dollar exchange rate and the petroleum are highly correlated[65].

[65] P. Artus, «Flash Marchés : Y-a-t-il vraiment un lien entre le prix du pétrole et le taux de change du dollar ? », Natixis, n°98, 2008.

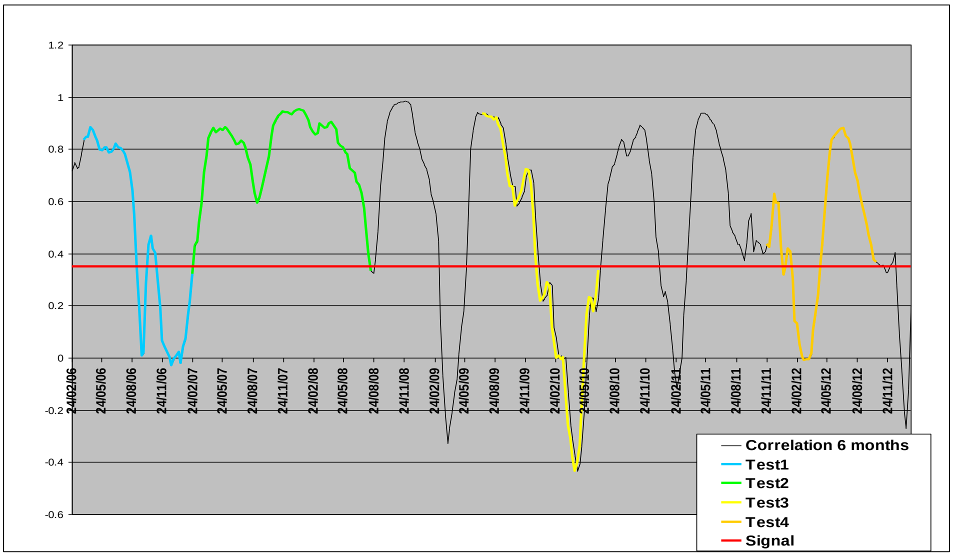
To do this we select four samples with our 0.35 indicator to analyze two with high correlation and two with low correlation. Our samples are selected like this: if the correlation crosses the historical 0.35 limit, and when the sample is important enough (at least 30 weeks), the sample could be appropriate. It is important to say that we take the prices 6 month before the crossings because we use a historical rolled window of 6 month to work out the correlation between our two variables. Because the important number of possible samples, we decide to focus on only four of them: the bigger gaps of correlation and the longer periods for high correlation.

We also make an analysis with the moving average indicator. We observe that our two techniques (Moving average and fix 0.35 signal) give the same results with only small differences. Indeed, there are only one or two week differences between the two techniques. It is why we decide to focus on the fix technique to make our analysis on the variables. However we will use the moving average indicator for our hedging strategy because it gives more signals and it is more dynamic to detect changes in correlation.

Here are the samples we selected with the fix indicator which are represented on the figure n°08:

-Test1: From 31/03/2006 to 23/02/2007: low correlation
-Test2: From 02/03/2007 to 15/08/2008: high correlation
-Test3: From 24/07/2009 to 09/07/2010: low correlation
-Test4: From 25/11/2011 to 19/10/2012: high correlation

Figure n°08: Sample selection



On this graph, you will find our data samples. The samples are before the crossings because we had already added the 6 month window except on the test 2 as explained below.

Source: Excel, Data from Bloomberg

For test 1, we make a small exception. Indeed, there are two crossings inside the sample, but there are very small. They would not exist if we had taken 3 or 4 month window for the correlation or if we have selected another arbitrary fix signal of 0.5 for example. Therefore, we decide to neglect those two small signals only to simplify our analysis. If not, we would not have been able to study two important different samples with low correlation.

For test 2, we do not proceed in the same way in what concerns the 6 month window. To avoid having common data between test 1 and test 2, we decide to reduce the number of observation in test 2 because there are more observations in test 2 than in test 1. This overlapping is possible because we work out the correlation with a rolling window of six months. We make the analysis with and without the "common" data and there is no impact on the results.

Finally, we also make two general samples with all the low correlation and high correlation data. Even if the results are not so clear, the conclusions are going in the same direction than with our four small samples.

3) *Analysis of the periods*

A) Introduction

We want to determine which variables could explain a change in the correlation between oil and Euro dollar Exchange Rate. To do this we have decided to make some Principal Components Analysis with many different variables to see differences between the samples of high and low correlation.

To analyze more accurately those differences of correlations, we first describe how we select the variables we decide to put in our study and why we do it in the following part of this work. After the explanation of our variables, we make a PCA on them to avoid the multicolinearity and to have a restricted number of variables.

Finally, we regress the Brent index in dollar on the factors we have obtained to analyze the links between our commodity and the variables we have selected. Those regressions are useful to test our indicator.

B) Selected Variables for the regressions

There are many possible variables which could have an impact on the price of the Brent crude Oil or on the Euro Dollar exchange rate. The first problem we have to cope with is to select the variables to study. The Brent Crude Oil is one of the most traded assets and it has links and correlations with nearly all financial assets and economic actors. So it's almost impossible to detect and to work with all of them, so we have to make some choices and to select a quite small number of possible variables.

In this part, we divide those possible variables into four categories: the monetary variables, the foreign exchange variables, the economic variables and the stress variables. In the following part of the work, we explain the composition of those categories and why we select them. As we said before, we take a sample of 7 years.

We know that there are other possible variables to include in our analysis but we believe that our categories are quite representative. We try to see the differences between those categories of variables during periods of low and high correlation. If there is important difference we will be able to explain and to detect the future changes of correlation. We are going to show you the tables n°04, 05, 06 and 07 with the codes we have used in our PCA analysis and the complete name. The complete description of the variables and the reasons why we choose them is in appendix n°005 of this master thesis. The column "n°" means the number of the explanation in the appendix.

a) Monetary Variables

This category tries to be a good sample of the monetary values and of the interest rates in the European Union and the United States for banks, states and companies. We show you the composition of this category. It is not as easy to interpret as the impact of the stress variables or economic variables. We expect that the European and the US variables will be different during low correlation and quite the same during periods of high correlation. So we could expect a difference between those economies and so it could lead to an important variation of the exchange rate.

Table n°04: Monetary variables

	Monetary Variables	
n°	***Code used in PCA***	***Description***
1	Inflation_france	The expected inflation rate in France
2	US_inflation	The expected inflation rate in US
3	Taux_SWP_inflation_FR	The rate of a 1 year inflation SWAP
4	swap_rate_curve	The expected evolultion of the Swap rate in France
5	Euribor	/
6	Libor	/
7	Spread_US_cmpny	Spread Between the US BBB bonds of companies and US Bond
8	Spread_EU_cmpny	Spread Between the EU BBB bonds of companies and German Bonds
9	EUSA_slope	The slope of the nominal interest rates in Europe
10	US_rate_slope	The slope of the nominal interest rates in US
11	EUSA_3M05	The forward European Nominal interest rate
12	Slope_Forward_EUSA	The slope of the forward rates

b) Foreign exchange Variables (forex or FX variables)

The exchange rates and the foreign currencies performances are also an important part of this thesis. Indeed, one objective of this work is to detect the effect of the exchanges rates on the correlation between the Brent oil and the Euro Dollar exchange rate. To do this we have selected some important exchange rates and some traded weighted index to insert the power of some currencies in our work. We try to represent the major economies in the world: US, Europe and Asia. As for the monetary variables we expect to see difference between US and European value which could lead to a difference between US and European economies and on the Euro Dollar exchange rate.

Table n°05: Foreign Exchange Variables

	Foreign exchange Variables	
n°	***Code used in PCA***	***Description***
13	Eurodoll	Euro-Dollar exchange Rate
14	Euroyen	Euro-Yen exchange rate
15	Euroruble	Euro-Rouble exchange rate
16	Asian_TWI	The trade weighted index for the Asian currencies
16	Yen_TWI	The Yen trade weighted index
16	Euro_TWI	The Euro trade weighted index
16	Dollar_TWI	The Dollar trade weighted index

c) “Real” Economy variables

By “real” economy, we want to represent the industrial activity, the company performances and all the other variables which are important for us. To do this, we include some index and metal prices. We are expecting to have a strong correlation between the oil price and the economic activity. Indeed, more activity could mean more consumption, and so more consumption of fuel. We will see if those values are different during high or low correlation periods.

Table n°06: Real economy variables

	Real economy variables	
n°	***Code used in PCA***	***Description***
17	SP500	The Value of the S&P 500 index
17	Eurostoxx	The Value of the Eurostoxx index
18	HSI	The Value of the Hang Seng Index
18	IBOV	The Value of the Bovespa Brazil Stock Exchange
19	copper	The Copper price
19	GSCI	The value of the Goldman Sachs Commodity Index
20	gold	The gold price
21	Var_Oil_RSV	The variation of the US Crude oil reserves
22	SPREAD_WTIBRENT	The Spread between the Brent oil price and the Wti oil price

d) Stress variables

It is very important to take the stress on the market into account. It is why we decide to choose three stress indicators. We will see if the values of the stress variables are different during low or high correlation or if it is the same whatever the correlation.

Table n°07: Stress variables

	Stress variables	
n°	***Code used in PCA***	***Description***
23	VIX	The CBOE volatility index
24	Liquidity_us	an indicator for the liquidity in the bank sector in US
24	Liquidity_EU	an indicator for the liquidity in the bank sector in EU

C) Principal Components analysis (PCA)

We have explained how to use PCA and how to interpret the results of this analysis in our theoretical part. Let’s use this theory in practice in this part of our thesis.

We do a PCA on each category of variables (Monetary, FX, real economy and stress) to obtain two or three factors for each kind of variables and for each sample of correlation. It first seems the best solution in our situation. But, even if the factors of the same category are not correlated together thanks to the varimax’s rotation, it appears that the factors are correlated between categories. For example, there is a strong correlation between the FX Factors and the monetary factors.

To solve this problem, we have decided to make a PCA with all our data for each period of correlation whatever the category. Our objective was to avoid multicolinearity in our linear regression. However were afraid to obtain factors which could not have been subject to a clear interpretation. Finally it appears that the interpretation of all the factors is quite easy and we succeed in analyzing our results.

Here are the results we obtain for each sample of correlation. We make a summary of the results because it would take too many pages to expose them in our thesis. We have decided to present you only two of the four samples we have selected but it is important to say that the other results lead to the same conclusions. The complete results are available in appendixes n°006, 007, 008 and 009 of this work. We are first going to explain the results for a low correlation period and we will finish with one high correlation period.

We analyze the results given by SAS after having run the PCA procedure we have written. We want to have an explanation of 90 % of the variance of our sample. When the cumulative sum of the proportions reaches this level we stop and we retain this number of factors in our rotation. We know that the last factors are quite similar and do not explain a lot of the distribution but we have to select a limit to make our analysis.

a) Test 1: low correlation[66]

Here is our first PCA on a period of low correlation. This table shows the results given by the FACTOR procedure.

Table n°08: PCA results Low correlation

Prior Communality Estimates: ONE

Eigenvalues of the Correlation Matrix: Total = 31 Average = 1				
	Eigenvalue	**Difference**	**Proportion**	**Cumulative**
1	14.7874911	10.1023504	0.4770	0.4770
2	4.6851407	1.1320796	0.1511	0.6281
3	3.5530611	1.1564637	0.1146	0.7428
4	2.3965974	0.6980871	0.0773	0.8201
5	1.6985102	0.8766581	0.0548	0.8749
6	0.8218521	0.0265802	0.0265	0.9014
7	0.7952719	0.1525797	0.0257	0.9270
8	0.6426923	0.2437844	0.0207	0.9478
9	0.3989079	0.1102178	0.0129	0.9606
10	0.2886900	0.0710585	0.0093	0.9699

Source: SAS Data from Bloomberg

We know that we have to retain 6 factors. We rotate them to make an interpretation and we obtain those rotated factors patterns. Remember, the rotated factors patterns indicate the variables which are highly correlated with the factors and so quite important to explain the factor and the variance of the sample. The following table shows the results given by SAS. The yellow cells indicate when the factor pattern is higher or equal to |55|. We choose this level to detect the relevance of the pattern. Higher or equal to |55| the rotated factor pattern is significant, less it is not.

[66] See appendix n°006

Table n°09: Rotated factors pattern

	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
Inflation_US	97	-1	1	0	-1	1
SLOPE_FORWARD_EUSA	96	-18	4	-9	-2	-1
EUSA_SLOPE	94	-20	-9	-15	9	1
US_rate_slope	91	-18	-11	-7	2	27
YEN_TWI	89	15	14	-13	-29	16
Inflation_France	75	30	23	3	32	3
VIX	68	2	46	-22	5	-25
SPREAD_US_CMPNY	66	-31	53	-4	-33	22
EURO_TWI	-64	64	-11	-15	20	-25
Eurostoxx	-80	9	-50	15	19	12
HSI	-84	22	-33	12	32	-5
SP500	-84	19	-45	7	17	6
EUROYEN	-88	21	-13	2	30	-20
ASIAN_TWI	-91	-30	2	18	12	-10
EURIBOR	-93	25	-2	12	20	-6
EUROROUBLE	-10	91	-16	-25	13	-8
EURODOLL	-51	81	-2	-13	15	-16
GSCI	-28	75	22	19	-11	35
GOLD	22	72	-38	17	39	-7
DOLLAR_TWI	-11	-90	-28	9	15	-2
SPREAD_EU_CMPNY	21	0	90	-1	-10	14
LIBOR	-37	29	78	6	21	-27
COPPER	47	42	57	13	-32	28
IBOV	-57	31	-65	2	35	5
swap_rate_curve	-13	-12	32	87	0	-17
Var_Oil_RSV	3	-23	-28	57	-2	15
Liquidity_US	42	-12	53	-55	-35	-2
Taux_SWAP_inflation_FR_1an	63	-1	3	-69	5	6
EUSA_3M05	-27	9	-15	-9	90	-16
Liquidity_EU	24	-10	2	-7	-7	88
SPREAD_WTIBRENT	12	-20	8	-43	24	-43

Source: SAS Data from bloomberg

We can see that the first factor is mainly explained by the monetary, the real economy variables and the VIX. There is no FX factor (except the Euro_TWI and the Asian variables but they are not the most important). We can say that factor one is the "Real economy and monetary factor".

The factor two regroups all the European and US FX variables (Euro_TWI, Dollar_TWI, Eurodoll and Eurorouble). Gold and GSCI are also present in this factor but less than the FX variables. It indicates that this factor is highly correlated with those variables (positive or negative correlation) and we can interpret this factor as “FX” factor.

What can we say after this analysis? The factor two regroups all the FX variables. It shows that there is a significant common correlation all those FX variables and that this correlation is quite important because it can be represented in one factor and this factor represents 15% of the variance. There is so a distinction between FX variables and other variables.

Moreover some US and European values as the liquidity and the “CMPNY SPREADS” are not in the same factors in this sample. It could mean that there is a disequilibrium between them and it could explain this low correlation. This is really important to see that it seems to be a desiquilibrium between US and European economies between periods of low correlation. There are other US and European variables which are different in the other sample of low correlation. But even if all US and European variables are not in different factors it seems to have a disequilibrium between them.

b) Test 2 high correlation[67]

To have 90% of explanation, we retain 6 factors.

Table n°10: Prior Communality Estimates: ONE

Eigenvalues of the Correlation Matrix: Total = 31 Average = 1				
	Eigenvalue	**Difference**	**Proportion**	**Cumulative**
1	15.3827693	10.4516830	0.4962	0.4962
2	4.9310863	1.3422973	0.1591	0.6553
3	3.5887890	1.4192455	0.1158	0.7711
4	2.1695435	1.1991309	0.0700	0.8410
5	0.9704125	0.0387483	0.0313	0.8723
6	0.9316642	0.1989864	0.0301	0.9024
7	0.7326778	0.0891944	0.0236	0.9260
8	0.6434834	0.1937881	0.0208	0.9468
9	0.4496953	0.0715566	0.0145	0.9613
10	0.3781386	0.1280084	0.0122	0.9735

Source: SAS Data from Bloomberg

[67] See appendix n°007

And the rotated factor patterns are on the following table.

Table n°11: Rotated Factor pattern

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
SPREAD_EU_CMPNY	94	31	-6	-5	0	6
US_rate_slope	91	29	-9	8	13	9
SPREAD_US_CMPNY	91	38	-7	-9	4	5
EURO_TWI	90	36	18	5	-8	3
EUROROUBLE	90	39	4	9	-10	1
EURODOLL	89	42	9	8	-7	-2
GOLD	87	38	-12	10	9	1
ASIAN_TWI	83	-12	40	-24	6	10
YEN_TWI	82	26	-47	-8	-10	-9
Inflation_France	81	27	42	8	2	-7
EUSA_SLOPE	-60	-9	-44	15	50	23
DOLLAR_TWI	-75	-64	-1	-11	-4	4
SP500	-91	18	12	17	-19	7
Eurostoxx	-96	13	0	12	-10	3
LIBOR	-97	-11	4	-7	4	-11
HSI	-8	94	4	0	1	-5
Liquidity_US	22	80	-12	-27	6	-11
Liquidity_EU	46	76	-1	-18	-24	-5
IBOV	51	73	16	21	-14	-2
SPREAD_WTIBRENT	30	71	-21	-13	15	-8
EURIBOR	59	64	33	-22	-3	-9
EUSA_3M05	2	-9	96	3	6	-5
EUROYEN	2	17	91	24	7	15
Taux_SWAP_inflation_FR_1an	23	12	81	-13	-32	-19
swap_rate_curve	35	-5	-56	-8	56	20
SLOPE_FORWARD_EUSA	11	38	-82	8	19	20
Inflation_US	-6	-13	8	80	20	-22
GSCI	-12	-35	-10	79	-25	24
COPPER	53	15	14	63	-14	23
VIX	47	43	-26	-20	48	-27
Var_Oil_RSV	10	-21	-18	2	6	83

Source: SAS Data from Bloomberg

There is a major difference with the first PCA. The majority of the economy, FX and monetary variables are in the same factor. It indicates that they are really important to explain the factor. There is no distinction between the FX and the other variables. Moreover the US and the European values are on the same factors which the same sign.

The other factors regroup different variables and it is impossible to determine an explainable signification. Except for the factors 5 and 6 which are explained by only one variable.

We make a linear regression to detect the impact of the factors on the Brent oil price on the following part.

D) Linear Regression on factors

After our PCA's, we have to test our indicator and to see the relations between our factors and the Brent oil price. To do this, we have decided to use linear regressions. We expect some results with those linear regressions: the FX factors or the factors with important FX determinants do not have to be significant if we are in a low correlation period. On the contrary, they should be significant if we detect a strong correlation period. We select an α of roughly 10% to test the significance of the coefficients.

If it appears to be true, it would mean that there is indeed a difference between those periods in what concerns the FX variables. If it is false, we will have to find another indicator to divide our periods.

We implement this following regression on SAS:

$$Brent\ Price = \alpha_1 * Factor_1 + \alpha_2 * Factor_2 + \alpha_3 * Factor_3 + \alpha_4 * Factor_4 + \alpha_5 * Factor_5 + \alpha_6 * Factor_6$$

Where α_x is the parameter to be estimated by the regression

It is important to say that we do not test the stationarity of our samples and the Brent price because we take the prices in level and not in returns and so our sample cannot be stationnary. We know that we will not be able to make statistical inference on our linear regression. Indeed we do not want to make statistical analysis or forecasting with our regression model but only to see the link between our factors and the Brent Oil price. It is why we consider that it is not dramatic in our study. The other results are in appendices. Finally, we do not consider the value of the R^2 because its value was not suitable in our case.

We will use the same two samples than before. The others studied samples are available in appendix n°010, 011, 012 and 013 of this thesis.

Here are the results given by SAS for our linear regressions.

a) Test1 : low correlation[68]

Here is the first step of the backward elimination of the REG procedure in SAS.

Table n°12: Linear regression Low correlation

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	64.91979	0.48376	202300	18009.3	<.0001
Factor1	5.79930	0.48888	1580.70095	140.72	<.0001
Factor2	0.76329	0.48888	27.38308	2.44	0.1261
Factor3	1.56082	0.48888	114.49922	10.19	0.0027
Factor4	-0.59270	0.48888	16.51057	1.47	0.2323
Factor5	-0.27603	0.48888	3.58100	0.32	0.5754
Factor6	-1.05828	0.48888	52.63780	4.69	0.0363

Source : SAS Data from Bloomberg

On this table n°12 which is given by SAS, we can observe that the « FX factor », the Factor 2 is not significant at 10%. It means that it seems that the FX

[68] See appendix n°010

variables are not good variables to explain the Brent oil price because they could not have the same trend. Factor 2 is not significant, our indicator seems to work.

b) Test 2 : High correlation[69]

Table n°13: Linear regression high correlation

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	92.54896	0.40960	659529	51053.5	<.0001
Factor1	20.24054	0.41228	31136	2410.18	<.0001
Factor2	6.21319	0.41228	2933.87974	227.11	<.0001
Factor3	7.65371	0.41228	4452.02212	344.63	<.0001
Factor4	0.93590	0.41228	66.56840	5.15	0.0263
Factor5	-1.00883	0.41228	77.34801	5.99	0.0169
Factor6	-1.84651	0.41228	259.12993	20.06	<.0001

Source : SAS Data from Bloomberg

All the factors are significant. It is possible to explain the Brent oil price with those variables, among which the Eurodollar Exchange rate. If the Brent price can be explained by those factors, it could mean that the variables represented in this factor are really important to explain the Brent oil price. Because the exchange rate and the Brent oil seem to have the same trend, it can indicate that we are in a strong correlation period, our indicator works as for the Weak correlation period.

E) Conclusion: Possible explanation and interpretation

We are shortly going to explain the differences of correlation between our samples that we have presented to you. We observe that there are some differences between those periods. The most important differences are between the liquidity indicators in US and in Europe and also between the companies spreads between the US and Europe. Those values are in red in the tables n°09 and n°11.

[69] See appendix n°011

During strong correlation periods, the US and European variables are represented in the same factors and with a similar factor pattern. This is not the case in the periods with weak correlation. It could mean that there are differences between the European and the US economies and that has an impact on the Exchange rate. This impact on the foreign exchange rate is not present on the Brent oil and it could explain the difference of correlation.

The factors which are explained by US values are always the most significant in our regressions during low correlation periods. It could mean that the Brent is more correlated to US economy than to EU economy. It is quite surprising because the Brent is extracted in Europe. We do not make other analyses to prove it and we take this explanation with caution because it is only an observation.

In conclusion, we find an indicator which can find different regimes of correlation between our Commodity price and our foreign exchange rate. We do not insist on the explanation of those differences but we find that there are differences between the US an EU economies. Those differences have a direct impact on the Euro dollar Exchange rate.

Now we are able to detect the periods where the currency risk becomes more important. Indeed, when the correlation decreases, the risk to know an increase of the currency risk is more important and we have to add a currency hedge to our commodity hedge. On the contrary, when the correlation is quite important, our two variables are moving together and they seem to be stable. It is so quite useless to make a currency hedge and so a commodity hedge is enough. (See the first part about the importance of the correlation in this thesis).

In the second step of our practical part, we will make some hedging strategies and we will compare them to select the most efficient one for each risk (currency and commodity).

c) Second step: Hedging strategies comparison

1) *Introduction*

Now we will speak about an important point of this thesis: the hedging strategies. We have succeeded in dividing our sample to determine if we have to hedge our position only on the commodity or if we have to add a currency hedge. We will first speak about the commodity risk because we have made more research to compare the strategies. After the commodity risk, we will propose a currency hedge to complete our master thesis.

We saw in our theoretical part how to create a hedge during one period of a determined length. In this part we also take the assumption of a client who has to create a hedge every trimester. We have to repeat the commodity and the currency hedges we have seen together every three months. So our study is a succession of individual hedges of three months during our sample of seven years (from the 24/02/2006 to 01/02/2013). All the calculation of this part are in the excel file called "Results_Benjamin_Brine.xls" on the attached CD.

2) *Commodity risk*

As we said in our theoretical part, the optimal hedge ratio is an essential principle to cope with as far as the implementation of a hedging strategy is concerned. There are a lot of studies about the optimization of the hedge ratio but there is no summary of all the possibilities. We try to gather all the information in this thesis about the hedging with futures (naïve, conditional hedge ratio) and hedging using options.

We begin this chapter by explaining the different hedges with futures (naïve, rollover, rolling window, conditional hedge, and hybrid hedge). After that we will develop how we priced our options and how we used them to create a hedge.

After that we will compare the different strategies to select the best one in our situation. We will expose the different reasons why we choose it and the pros and cons of this choice.

Before coming to the analysis of our hedges, we will explain which criterions we use to measure the performances of the strategies: the variance indicator and the variations of price indicator.

A) Measures of performances

In the majority of the studies we have read the reduction of variance is the most used indicator to measure the performance of a hedge[70]. However we want to include another indicator in our analysis. Indeed, we want to create a hedge which reduces the variance of the Brent but which also permits to take some profits thanks to our strategy. It is why we also choose the average variation of prices as an important indicator. We now explain why in detail.

a) Variance indicator

We choose this indicator because it is used in an article on which we base our analysis: J.Cotter and J, Hanly, "Reevaluating Hedging Performance", the journal of future markets vol.26, 2006. The formula given by J Cotter and J Hanly is as follow:

$$Variance\ reduction = 1 - \frac{Variance_{Hedged\ returns}}{Variance_{\ spot\ returns}}$$

We actually make the variance on the returns of the spot price and hedged prices. The hedged price is the variation of price during your hedge. A positive return means that you pay a higher price than the spot which is applicable at the moment you have decided to hedge and inversely. This is NOT the return between the prices paid after the hedge but the return between the spot price and the hedge price every three

[70] J.Cotter and J, Hanly, "Reevaluating Hedging Performance", the journal of future markets vol.26, 2006.

months. We work out the hedged return on the spot price of the previous period like this:

$$Hedged\ Return_t = \frac{Hedged\ Price_t - Spot\ Price_{t-3}}{Spot\ price_t - 3}$$

Where:

-the hedged price is the price obtained after the hedge (the profit or the loss on the derivative position is so taken into account)

-t is the moment when we work out the return

-t-3 is the moment when we decided to hedge.

This way we obtain the variation of price in percentage, also called the return after the hedge. For example, with a return of 1%, it means that the price has increased by 1% even if we have created a hedge. This is NOT the return between the hedged prices. This way we will obtain returns which correspond to each hedge. The variance of the unhedged portfolio is the variance of the returns of the spot prices.

For example, we decide to make a hedge when the spot price is equal to 60$. To do this we buy futures contract at 61$ with a maturity of 4 months. Three months after we sell our futures contract at 65$ and the spot price is equal to 67$. Our profit on the position in futures (or roll) is equal to 65-61=4$ per barrel. This leads to a hedged price equal to 67-4=63$. Indeed we subtract the value of our roll to the spot price. So the Hedged return is equal to $hedged\ return = \frac{63-60}{60} = 0.05 = 5\%$. This means that the price has increased by 5% even if we have made a hedge. But this is less important than the return with no hedge which is equal to $\frac{67-60}{60} = 11.6\%$. We work out the variance of those returns to obtain the variance of the hedged returns and the spot returns.

The advantage of the variance indicator is that we can easily interpret the results. When the indicator is near the value of one, the hedge performs well in the reduction of variance. Near zero, it means that it does not really work to reduce the variance. A reduction of variance is the same as a reduction of the risk. Indeed if the variance is small it means that the returns are weak.

The disadvantage of this measure is that it takes the variability of the returns into account and it gives an equal weight to negative and positive returns.[71] We want to have a better indicator to determine which strategies give the best returns for our client, in our case, negative hedged returns because we consider importations of fuel. It is why we choose to develop our next indicators.

b) Variation indicators

As we have just said just before, we decide to include other indicators in our analysis because the variance indicator gives the same weight to an increase or a decrease of prices. We use the variation in price and not the return to compare easily the values.

The interpretation of the maximum variation: the more important is this maximum, the less effective is your hedge. It means that your hedging strategy does not work as a protection because even if you pay to create your strategy, you are not protected against an increase in the price. It means that the benefit of your position in derivatives cannot compensate the variation of the spot price.

The minimum is the contrary. The more negative is this variation the more important is the profit you can get from your strategy. It means that you can make a profit from an important decrease of the prices. Your strategy does not fix the price "ad vitam eternam".

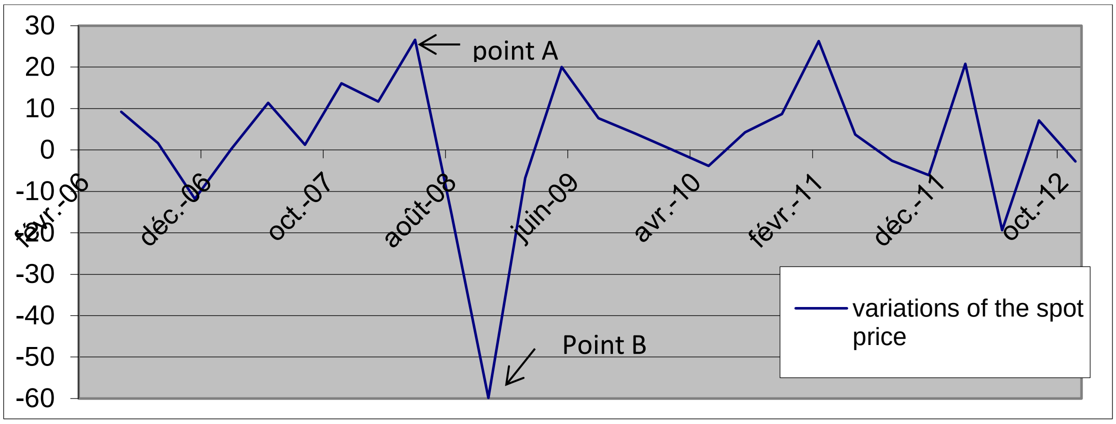
The average price variation. This indicator is also really important to test the effectiveness of our hedge. Indeed, when you have an important positive average it means that, in average, you pay a more expensive barrel even if you implemented a hedging strategy. If this average is negative, it means than, in average, you pay less than expected for your barrel (the price is lower thanks to your hedge and it is good

[71] J.Cotter and J, Hanly, "Reevaluating Hedging Performance", the journal of future markets vol.26, 2006.

for you). Another point of view is that when this average variation is negative, the profit of your position in derivatives is more important than the variation of the spot price: you win money thanks to your hedge. If you multiply this average by minus one, it can be also interpreted as a profit. We use this gain in our final analysis.

You can see an example on the figure n°09 which represents the variation indicators for the spot prices:

Figure n°09: Spot price variation



Data from Bloomberg

The curve represents the spot price variation in Dollar ($Spot\ price_{\ t} - Spot\ price_{t-3}$). In this case the variation indicator for the blue curve is equal to:

-Maximum variation = 26, 6$ (Point A)

-Minimum variation = -59.88$ (Point B)

-The average variation= average of the curve = 1.93$. On average the price increases by 1.93$ each trimester.

B) <u>Hedging with futures</u>

We use the data available on Bloomberg in our analysis. As mentioned earlier we use an index on the Brent crude oil as spot price. It is important to say that we consider a standardized quantity of barrel of 1000 per futures contract. However we consider a barrel to barrel hedging for the standard naïve hedge. We make all our calculations for the OHR in returns and not in price variation. It is also correct according to the literature[72].

[72] The returns are used in this study: J.Cotter and J, Hanly, “Reevaluating Hedging Performance”, the journal of future markets vol.26, 2006.

a) The use of generic futures

It is important to say that we do not use “normal” or “real” futures prices but generic futures prices. If we had used real futures prices, we would have had to download almost 200 different prices and it would have taken too much time for BNP Paribas Fortis. It is why we choose the generic contract because we gather all our data in only one download on Bloomberg.

A generic 4 month futures price is the price we would pay for a 4 month futures contract. The maturity of the contract is always the same and equal to 4 months because the maturity does not decrease over time. You can say that it brings problem in terms of volatility (and so the variance) or correlation because of the Samuleson effect (the correlation changes with the maturity of the contract). However we test this and there is no problem in terms of variance or correlation.

We proceed this way: we test if there is a significant difference between the variance of t month generic contracts weekly returns and the variance of t+3 month generic contracts weekly returns. Indeed if there is no significant difference between them, there is no difference with a normal contract because its variance has to be between those “generic” variances.

On the contrary if there is a significant difference, we will not be able to use generic contract because it means that the variance is really different during the life of the contract. But fortunately the difference is not significant. We can say that the difference of volatilities between “real” and generic futures is negligible during only three months. The calculations are in the page n°16 of attached excel file.

b) Standard Naïve hedge

- Explanation

This hedge is the easiest one to implement and to understand. We consider that we can cover each “spot” barrel by one futures barrel. So the OHR is equal to one. When you decide to create a hedge for a determined quantity of barrel, you have to buy the same quantity of barrel with futures contracts.

Concretely, at the beginning of the trimester we buy one 4 month futures contract which is virtually over one oil barrel. After three months we sell this contract at the price of futures of one month. We obtain the result of our position in futures contract which compensates the variation of the spot price. We will not consider futures contracts with different maturities in this case.

For example:

D) In time t-3: spot price =60$, futures price 4 month maturity= 61$.

E) In time t: spot price = 65$ and futures price 1 month maturity= 67$.

The roll which is equal to the variation of the futures prices is equal to 67-61=6$ and this can be compared to a profit. The variation of the spot price is equal to 65-60=5$. The price paid for the barrel after the hedge is equal to spot price in t minus the roll and is equal to 65-6=59$. The hedged return is equal to $\frac{59-60}{60} = -1.67\%$. This way we can obtain a cheaper barrel thanks to our hedge in our example. We repeat this operation every three month; we work out the hedged returns and the price variations to work out the values of our indicators.

- Performance

The performance of this strategy is as follow:

Table n°14: results standard Hedge

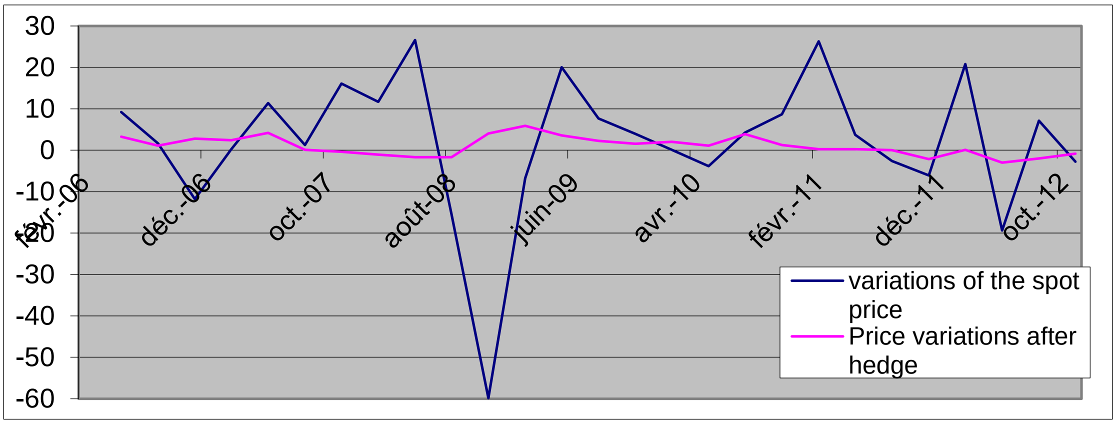
Performance	
Variance of the returns (no hedge)	0,034195771
Variance of the returns (hedge)	0,001137504
Variance indicator	0,966735536
Average variation	1,02
Minimal variation	-3,00
Maximal variation	5,89

Source: Excel, Data from Bloomberg

You can see that our hedge can reduce quite well the variance of the returns (96.68% of the variance). But on average you still pay a higher barrel price than expected: 1, 02$ of price increase even if there is a hedge. However, this is still better than the average variation without hedge which is equal to 1.93$ (see figure n°9). The minimum variation without hedge is equal to -59, 88$ and the maximal is equal to 26.6$ as showed in the figure n°09. This hedge performs very well to reduce the variance of the prices.

Figure n°10 shows the price variation during our successive hedges. You can see that sometimes the variation is positive (a more expensive barrel than the spot price when you decide to hedge) and sometimes the variation is negative (a cheaper barrel thanks to the hedge). We will come back to this point in our part about the hybrid strategy.

Figure n°10: variations of price



Source: Excel, Data from Bloomberg

c) Rollover hedge

- Explanation

We choose to make a rollover hedge because we read a lot of articles about that kind of strategy and Metallgesellschaft. To do this, we buy one two month futures contracts on one virtual barrel and sell it one month later (OHR=1 each month). Each trimester we sum the rolls and we work out the price paid at the end of the trimester. The returns are worked out with those prices and the spot prices.

Those rollover strategies are usually used when the liquidity of the futures contracts is not so important or when the correlation between spot prices and futures prices for important maturities is very weak. However this is not the case for the futures on Brent oil. We do not really insist on this strategy firstly because it is not useful in our case and secondly because it is more expensive than the standard hedge because of the transactions costs and the performances are similar.

The principle is the same than for the standard naïve hedge except that the roll is equal to the sum of the monthly differences of the prices of the futures contracts:

$$Roll_t = (F1_t - F2_{t-1}) + (F1_{t-1} - F2_{t-2}) + (F1_{t-2} - F2_{t-3})$$

Where:

-$Roll_t$ Is the trismestrial roll

-$F1_t$ is the futures price with 1 month maturity at time t

-$F2_t$ is the futures price with 2 month maturity at time t

- Performance

Table n°15: results rollover hedge

Performance	
Variance of the returns (no hedge)	0,034196
Variance of the returns (hedge)	0,001386
Variance indicator	0,95947
Average variation	1,007037
Minimal variation	-4,15
Maximal variation	6,78

Source: Excel, Data from Bloomberg

As you can see the strategy is less performing than the first one but the difference is very small. And on average, this strategy leads to a higher price of the barrel. We will not use this strategy because it is very expensive and those costs do not bring to a better performance.

d) Rolling window hedges

- Explanation

Now we add another element to our standard naïve hedge: the volatilities and the correlation between futures prices and spot price vary over time. But we are always in a naïve assumption: we suppose that the correlation of the last three months will also happen in the next trimester.

We make our analysis with contracts of different maturities: 4, 6,12 and 24 months to cover our position ***during one trimester***. Indeed, we have seen that the shape of the futures prices curve could have an effect on the roll. We study the differences.

We proceed like this to play with the maturities:

F) 4 months: We buy a 4 months futures and sell it 3 months later (price = 1month futures). This is a strategy with the nearest month futures.

G) 6 months : contract bought : 6 months; contract sold: 3 month futures

H) 12 months: contract bought 12 months; contract sold: 9 month futures

I) 24 months: contract bought 24 months; contract sold: 21 months

We work out the standard deviation and the correlation between futures returns and the spot returns with excel formula. We use daily data to have enough observations and to have good estimations of the standard deviations and correlations (60 returns for each). After that we use the formula we saw in the theoretical part to obtain our OHR also called h*. We do not use the price variation but the returns in this case [73](see theoretical part for details):

$$h^* = \rho \frac{\sigma_S}{\sigma_F}$$

[73] The returns are used in this study: J.Cotter and J, Hanly, “Reevaluating Hedging Performance”, the journal of future markets vol.26, 2006.

Once we have this value, we make the daily clearing to get the optimal number of contract to buy (see theoretical part for details):

$$N^* = \frac{h^* V_A}{V_F}$$

We obtain the right number of contracts per trimester. Then we determine the profits on the position in futures, we work out the price we pay for each barrel in our hedge and we are able to find the value of the hedged returns to measure the performance. Here is the formula:

Price paid= spot price – roll

Where:

The roll is equal to the profit on the position in futures. (Price sell- price bought)

- Performance

Here are the results of those hedges. CO4 means that we made a hedge with 4 month contracts, CO6 with 6 month contracts, and so on.

Table n°16: results rolling window hedge

Performance	CO4	CO6	CO12	CO24
Variance of the returns (no hedge)	0,034196	0,034196	0,034196	0,034196
Variance of the returns (hedge)	0,001361	0,001436	0,002249	0,004967
Variance indicator	0,960214	0,958011	0,934236	0,854752
Average variation	0,915444	0,717492	0,10396	-0,44239
Minimal variation	-3,29489	-5,03714	-9,38787	-14,4081
Maximal variation	5,058432	5,209387	5,65912	7,889951

Source: excel, Data from Blommberg

You can see that when you hedge your position with contracts with a nearer maturity, the reduction of variance is more important. However, the contracts with distant maturities perform better in terms of average variations: you get on average a cheaper barrel when you use contracts with more distant maturity. The maximal variation is less important with CO4 contracts than with CO24 contracts. However, the maximum variation with the CO24 contracts is less important than without hedge see figure n°09. It is still better to hedge yourself with CO24 contracts than to make no hedge at all. We can see that there is a trend in the results but the differences are not significant[74].

The rolling window hedge with CO4 contracts performs quite exactly the same way as the standard naïve hedge (0.96 instead of 0.959) in terms of variance reduction. As far as the average price variation is concerned, the CO4 rolling window performs a little bit better but it is not really different (0.91$ instead of 1$). On average you pay your barrel 9cents less if you use the rolling window hedge. This is negligible.

You have to choose your contract the following way: if you only want to reduce the variance, choose the nearest maturity possible. If you want to take more risk and to pay in average less money, take contracts with a more distant maturity. It depends on your risk aversion.

e) Hybrid Hedges

- Why to take Backwardation and Contango into account?

Let us take the table n°16 again:

Those differences of variance reductions can be explained by the volatility term structure. We have seen that the nearest month futures are always more correlated with the spot price than the contracts with more distant maturities. And this strong correlation explains how the CO4 contracts reduce more the variance than the CO24 contracts because the prices evolve together and have the same variation.

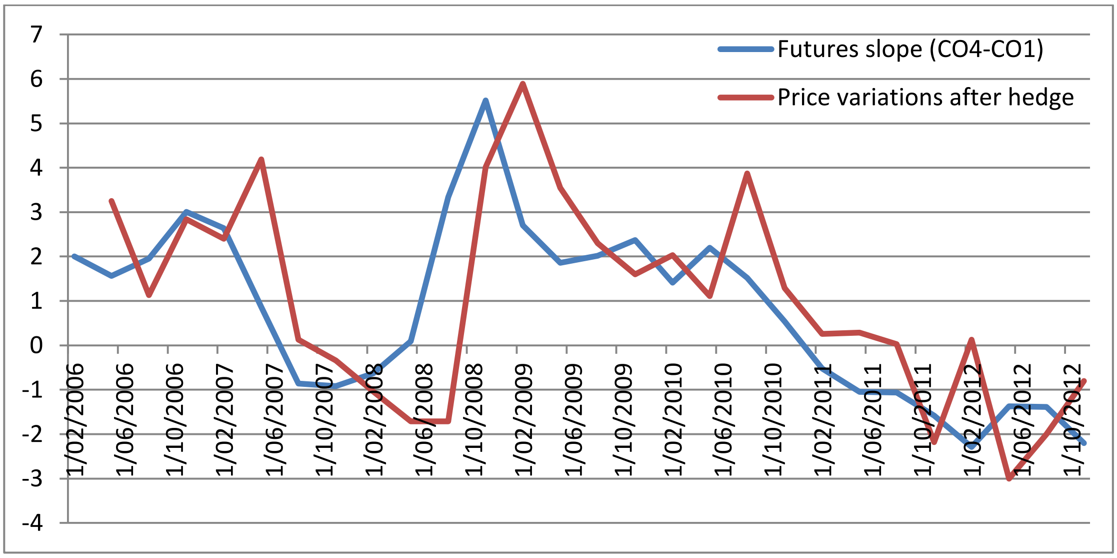
The differences of average variation of price are explained by the slope of the futures prices curve. We have seen that during backwardation periods (negative slope) that the rolls bring profits and bring losses during contango periods. We have also seen that the contracts with nearest maturities are often subject to change in the slope

[74] See excel file for the calculations

due to informational shocks. This principle explains how the CO24 contracts are less subject to those changes and the averages of the price variations are less important because they are less subject to important losses due to informational shocks. Therefore they have, on average, a negative price variation (the barrel is cheaper).

We prove this fact by showing you again another version of the graph which represents the price variation of the standard naïve hedge, the figure n°11. We add an indicator for Backwardation or Contango period. We subtract the price of the one month futures from the 4 months futures. If this indicator is positive, it means that the slope is positive. If the indicator is negative, the slope is also negative. The y axis represents the differences of prices in $.

Figure n°11: Futures slopes

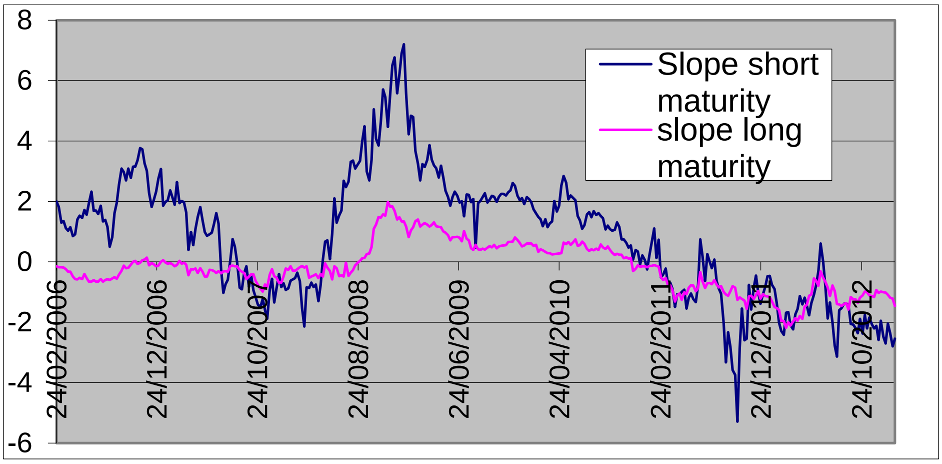


Source: Excel, Data from Bloomberg

You can see that, in general, the price variations during your hedge are negative when the market is in Backwardation. And the variations are positive when the market is in Contango. So we have to find a solution to increase the number of negative price variation because it is better in our case: we pay a cheaper barrel.

We have said before that the contracts with a longer maturity are less subject to Contango or Backwardation effects. Let us prove this thanks to a little chart, the figure n°12.

Figure n°12: Backwardation indicator

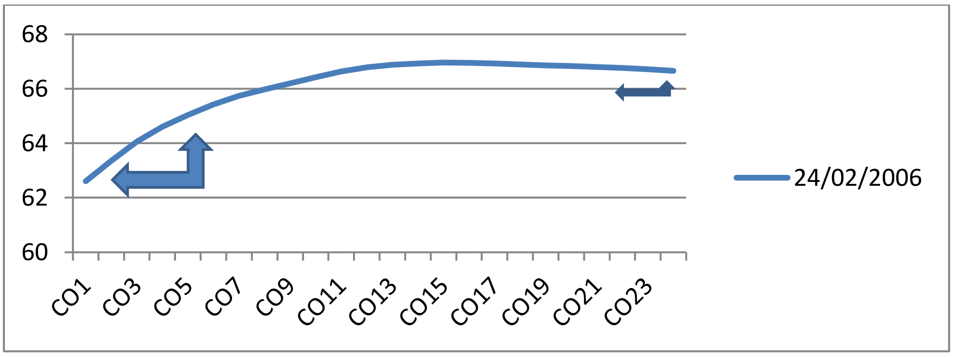


Source: Excel, Data from Bloomberg

The figure n°12 shows the evolution of the futures curves slopes over time. The "short maturity slope" represents the price of the CO4 minus the price of the CO1 contract. The "long maturity slope" shows the price of the CO24 minus the price of the CO21 contract. When the value is positive, it means that you are in Contango and that the rolls are as a cost. When the value is negative, you are in Backwardation and the roll brings profits. You can see that the "slope long maturity" changes less over time, this slope is flatter that the other one.

The figure n°13 represents the term structure of the futures prices on crude oil: when the market is in Contango, the roll of using a hedge with CO24 contracts is less negative than the roll if you had used CO4 contracts (in this case the roll is even positive.) In other words, in case of Contango it seems to be more useful to use 24 month contracts than 4 month contracts to avoid this cost because the slope is less important.

Figure n°13: Roll example



Source Excel, Data from Bloomberg

You can see on the figure n°13 that the slope is always less positive on the right end of the term curve, so the roll is less expensive for the CO24 contracts in case of Contango. But the roll brings also fewer profits in case of Backwardation. This is the principle of the hybrid hedge.

- Explanation of the hybrid hedge

Because of those previous elements, we want to create a hedging strategy which will take benefits from the futures price term structure. This strategy works as follow: when the market is in Contango (the indicator CO4-CO1 is positive) we use the CO24 contracts in our hedge to avoid the losses on the negative roll. When we are in backwardation, the slope CO4-CO1 is negative and we use the CO4 contracts to take profit from the positive rolls.

This strategy can be a compromise between the volatility reduction (because the CO4 contracts are strongly correlated with the spot prices) and the negative price variations due to the use of the CO24 contracts. We will see together that it works.

The calculations are still the same. We use a rolling window hedge because it takes the changes of correlation into account and it is a better assumption than the standard naïve hedge.

- Performance

Table n°17: Results hybrid hedge

<u>Performance</u>	
Variance of the returns (no hedge)	0,034196
Variance of the returns (hedge)	0,004305
Variance indicator	0,874115
Average variation	-0,82664
Minimal variation	-14,4081
Maximal variation	7,889951

Source: excel, Data from Bloomberg

The reduction of variance is better than the hedging which uses only the CO24 contracts and worse than the other one. The average price variation is better than for the other strategies. So we can take benefit from the futures prices curve. We reach our objective. In terms of minimal and maximal variation, the results are the same than for the CO24 rolling window strategy.

This strategy seems very attractive to us because it appears to be a compromise between the variance reduction and the minimization of the price variation. With this hedge we can reduce the variance and obtain a cheaper barrel.

Now it is time to delete our naïve assumptions and use the GARCH modeling to obtain the conditional values.

f) Conditional hedges

- Explanation

After using naïve hedges, it appears that the naïve assumption is quite reductive. Therefore we tried to create a GARCH model to work out the conditional values which are useful to obtain our optimal hedge ratio.

However, we have known some problems to implement our model on SAS with the dedicated procedures like Proc reg or varmax because of the lack of observations. Indeed, we want to work out the correlation and standard deviation on a sample of three months each. Our sample of 7 years was made of 28 trimesters and so we had only 28 observations to run our procedure and it was unfeasible. We find another solution to work out the conditional values by using the model procedure.

Moreover, it is impossible to have a DCC GARCH model on SAS, we try to use the BEKK model in the Varmax procedure but the results are not really good (only the constant was significant). We abandon this technique and work out the covariance thanks to the model procedure[75]. Indeed, as for the volatility, the

[75] The SAS procedure is available in appendix n°14

covariance can be estimated with a GARCH model[76]. We directly used the results of the volatilities and the covariance given by SAS to work out the conditional correlation. It is like a "manual" DCC GARCH model.

We do not insist on the GARCH result but we are aware of the fact that we have had some difficulties to obtain our values. However we decide to present you the results because we prefer to present you an imperfect model than presenting nothing at all. The SAS results are available in appendices n°015, 016, 017, 018 and 019. We directly use the values of the volatilities and the covariances given by SAS to determine the conditional correlation and so our OHR even if the models are not perfect.

- Performance

Table n°18: results conditional hedges

Performance		
	CO4	***CO24***
Variance of the returns (no hedge)	0,034196	0,034196
Variance of the returns (hedge)	0,001325	0,004448
Variance indicator	0,961264	0,869937
Average variation	0,840364	-0,28404
Minimal variation	-4,18479	-13,7057
Maximal variation	5,443054	6,847117

Source: Excel, Data from Bloomberg

As you can see the results are quite similar to the naïve rolling window hedge. Even if it seems that the conditional hedges perform better, the differences are not significant. It is the same for the average variation indicators.

g) Conditional hybrid hedge

- Explanation

We develop the conditional version of our naïve hedge. Because the unique difference is for the calculations of the volatility and the correlation, we do not come back to explanations about the model.

[76] J. Hull, « Options, Futures and other derivatives », New Jersey, Pearson, 8th edition, 2011.

- Performance

Table n°19: results conditional hybrid hedge

Performance	
	Garch Hybrid
Variance of the returns (no hedge)	0,034195771
Variance of the returns (hedge)	0,003931529
Variance indicator	0,885028798
Average variation	-0,625300826
Minimal variation	-13,70573656
Maximal variation	6,847116916

Source: Excel, Data from Bloomberg

As you can see, the conditional hybrid hedge performs a little bit better than the naïve hedge. But this difference is so small that it is not statistically significant. Moreover the other indicators as the variations indicators do not indicate a real difference between conditional and naïve hedge.

A question to answer is: is it really interesting to use a difficult and complicated model as the conditional model if the difference is so small with the naïve model? Moreover we are aware that our GARCH model is not completely academically correct.

C) Hedging with options

One objective of the options is to create hedging strategies for investors. We will see in this part how it works. We first shortly explain how we priced our options. After that we will see how to create a hedge with those options and finally we will analyze the performances of this hedge.

a) Pricing

As we have said in the practical part we use the Black Scholes and Merton model to price our calls. There are other ways to price options but we do not really insist on them because this is not the direct object of this thesis. It is important to say that we consider that the assumption on which the model relies are respected.

All the calculations are available in the page 11 of the attached Excel file. We consider the daily historical volatility to make our pricing and not the implicit volatility. It is said in our reference book (Hull) that it is also correct. We make sure that the value of this volatility can be used in the Black Scholes and Merton formula as explained in our reference book.

It is not possible to use a direct riskfree rate. To obtain a correct value of the rate to use, we worked out the discount rate used to obtain the 3 month futures price on an empirical way by using this formula:

$$F_0 = S_0 e^{(r+u-y)T}$$

Indeed, we consider that in our case the convenience yield is like a dividend. This assumption is correct according to the literature because we consider the Brent as a good of consumption. It is why we included the yield (r+u-y) we have obtained before to price our option instead of the riskfree rate.[77] [78]

In our case we obtain the price of a call which gives the right to buy one barrel at a given price in three months (the maturity). The strike price is determined as the spot price when the company has to price the option, we use option at the money.

b) Hedge

Once we obtain the price of the option every three months (P), we are able to begin the hedge. We consider the buy of a call with a maturity equal to three months and a strike price equal to the spot price when we buy the option.

We also consider that two cases can happen: when the actual Brent price (S) is higher than the strike price (K), we use our option, when the actual spot price is lower, we do not use the option.

[77] J. Hull, « Options, Futures and other derivatives », New Jersey, Pearson, 8th edition, 2011.
[78] A Eydeland and K Wolyniec « Energy and Power Risk Management : New Developments in modeling, Pricing, and Hedging", ed WileyFInance

The price we pay for our barrel (B) can be equal to two values:

J) If K<S, B=K+P : example 1

K) If K>S, B=S+P : example 2

Example 1, we pay 5€ for a call at the money which is over one barrel. The strike price is equal to 60$. If the spot price at maturity is equal to 70$ we use our option and we pay strike price+ premium of the option = 60+5=65$. This is better than the spot price of 70$. We make a profit with our hedge

Example 2, price of the option = 5$; strike price equal to 60$. The spot price at maturity is equal to 50$. We have to add the premium of the option to the spot price and so the price we paid is equal to 50+5=55$. This is higher than the spot price, we make a loss with our hedge.

After that, we are able to determine the value of the different returns and the two indicators to measure the performance of this hedge.

c) Performance

Here are the results:

Table n°20: Results option hedge

Performance	
Variance of the returns (no hedge)	0,034196
Variance of the returns (hedge)	0,012232
Variance indicator	0,642287
Average variation	0,529542
Minimal variation	-51,4196
Maximal variation	9,254031

Source: Excel, Data from Bloomberg

The option hedge performs less in terms of variance reduction, but it is normal because you only cover the price increases and not the price decreases.

However, the option hedge performs better in terms of minimal variation. With options you can take benefits from a price decrease which is no possible with futures.

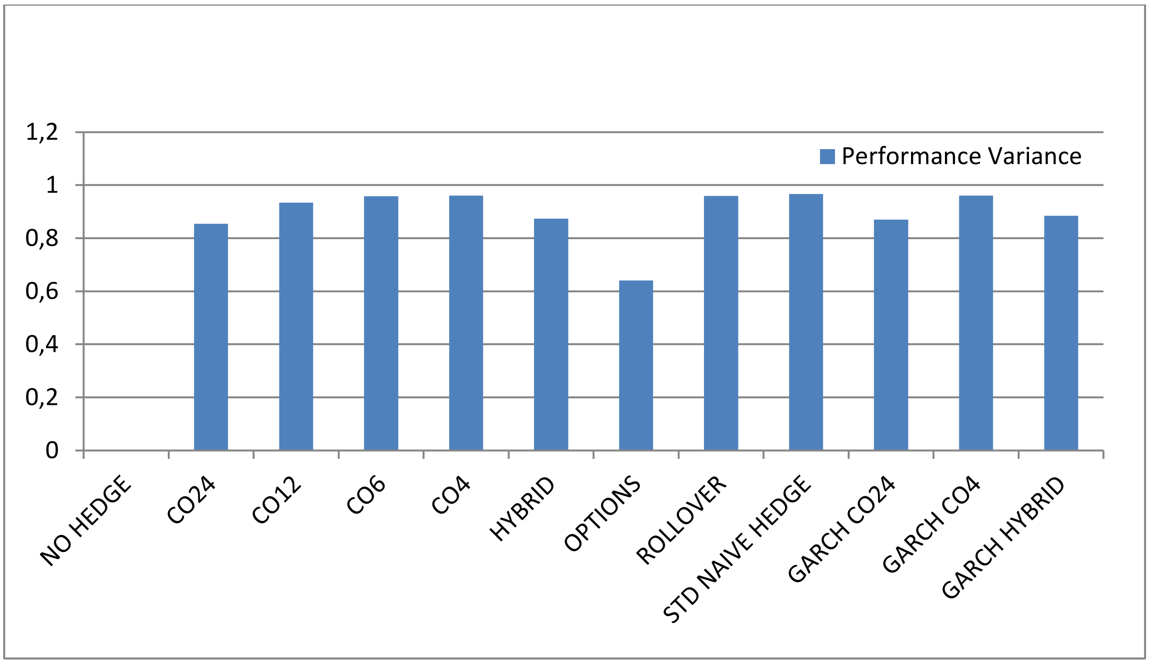
But the average is higher and positive; the cost of the options has an important impact on the final price of the barrel.

Finally, options are quite good to hedge yourself on a price increase but this strategy is more costly. If you always want to fix the price, futures are more suitable, if you want to benefit from a decrease of the prices, the options are better.

D) Comparison

Here is the summary of all our results about the reduction of variance of the commodity hedges. As you can see the futures hedges are quite similar in terms of variance reduction (between 85 and 97%). The option hedge performs less but we have seen together that it was normal because we are only hedged in case of a decrease of price.

Figure n°14: Variance comparison



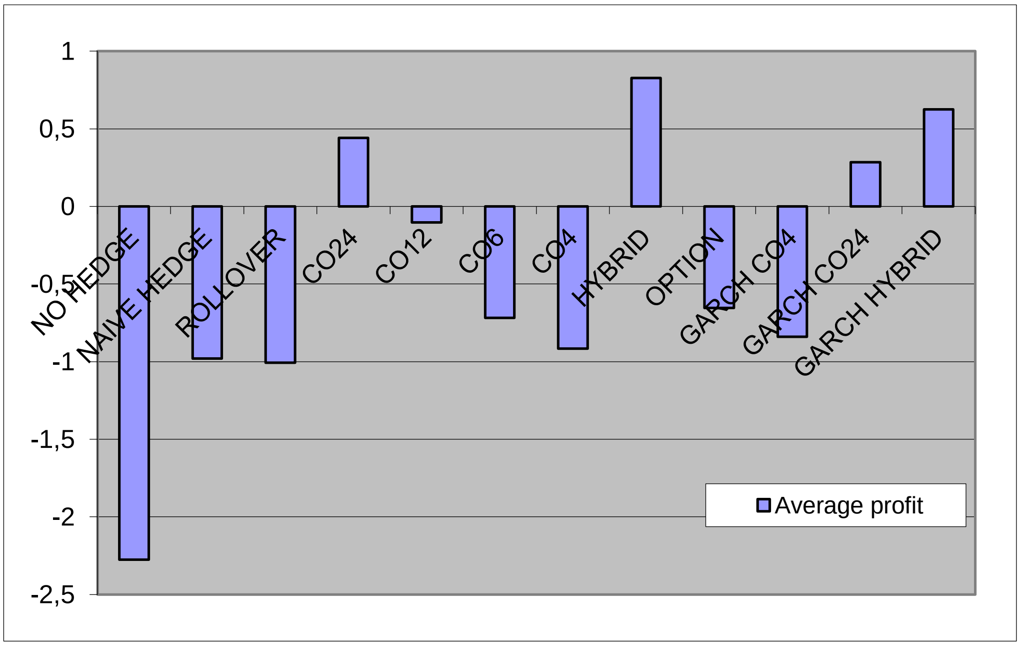
Source: Excel, Data from Bloomberg

There is no significant difference between the naïve and the most sophisticated hedges. We have seen previously that our GARCH models are not completely correct but it cannot be the only possibility to explain this weak difference of performance.

Indeed, it is said in the literature[79] that GARCH models do not perform very well when they are used in a long term perspective. We used GARCH models in a three month perspective which is quite long term. So this difference seems to be normal but we do not have enough time to study this in detail.

We will now analyze our second main indicator, the average price variation on the figure n°15.

Figure n°15: Average price variation comparison



Source Excel, Data from Bloomberg

We multiply the average price variation by minus one to obtain a positive value in case of a profit to make the interpretation easier. This is the only change in comparison with the previous average variations.

Only the hybrid hedges and the CO24 hedges permit to obtain a cheaper barrel on average. On average the other used strategies do no permit to fix completely a price equal to the spot price when you decide to hedge. Moreover the hybrid hedges perform better than the CO24 hedges. We can say that playing with the maturity of the futures contracts has a positive impact on the price of the barrel.

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[79] J.Cotter and J, Hanly, "Reevaluating Hedging Performance", the journal of future markets vol.26, 2006.

E) Hedge selection

We will now explain which hedge we will use to make our simulation which includes the currency risk and momentum indicator. This will be the third part of this thesis.

To respect our simplicity criterion, we choose the naïve techniques with futures. Moreover, the differences with conditional techniques are small and no significant. If the most sophisticated hedge had performed clearly better, we would have chosen one of them but it is not the case.

As for the cost criterion, we dismiss the option hedge because we have seen that is is more costly to implement. Even if it is a well performing strategy, it is not the same point of view than with futures hedge. Finally, we choose the hybrid naïve hedge among the naïve futures hedges because we have seen in the comparison part that this strategy can lead to a cheaper barrel with the variance reduction.

3) Currency Risk

We have already exposed our results about the commodity hedge. We will now expose our researches about the currency hedge. We will only use forward contract because it is the most used method at BNP Paribas Fortis and the simplest method too. We will first explain a perfect hedge and then a hedge which includes other indicators (we will call it the improved hedge).

All our calculations are available in the Excel file. To be more succinct, we will use sometimes the abbreviation FX (foreign exchange) hedge instead of currency hedge.

A) The perfect hedge

We will now explain the perfect hedge with forward. We will not use this method in our simulation but it is a good first step before going into detail.

As we have said in our theoretical part, we obtain the forward rate by adding or retrenching the points given by Bloomberg from the spot exchange rate. After that we have to buy a determined amount of forward contracts to cover the amount of the transaction, in Dollar. We do not consider a specific amount of currency because we only take the fixed exchange rate and we transform in Euro the value of the average barrel spot price in Dollar.

To measure the performance of this hedge we will use two indicators: the reduction of variance and the comparison of the average spot price of the barrel with and without hedge in Euro.

Here are the results:

Table n°21 Results FX hedge

Performance	
Variance no hedge	0,003282
Variance hedge	7,82E-06
Variance indicator	100%
Average barrel price without hedge	64,11432
Average barrel price with hedge	64,36136

Source: Excel Data from Bloomberg

As you can see, the hedge works perfectly to reduce the variance, and it is normal. However the spot barrel price in Euro is a little bit higher with than without hedge. It means that this hedge is very good to reduce the uncertainty but in final, you pay on average a higher price than the spot price in Euro when you decide to hedge your positions.

B) The improved hedge

The objective of this hedging strategy is to be only covered during the decreases of the exchange rate. To do this we will use the periods of correlation and a moving average.

Remember: we have found in the first step of our practical part that when the historical correlation between the Euro Dollar exchange rate and the Brent price is lower than usual, the exchange rate knows an important variation. It is why we will only focus on those periods of low correlation. We will use the 6 months moving average of the 6 months historical correlation. When the historical correlation will cross down the moving average, it will be a signal of low correlation.

Even if we succeed in the detection of the future important variations of the exchange rate, we want to detect only the decreases. Therefore we include a 3 months moving average of the Euro Dollar exchange rate to detect if there is an upward or a downward trend during this period of low correlation. In case of a low correlation period and in a downward or stable trend we will buy forward contracts to be hedged against a possible fall of the exchange rate.

We also decide to look at the 1 month moving average of the Euro Dollar exchange rate when it is difficult to take a decision with the 3 month moving average. When the 3 months moving average is quite stable, or when the trend seems to reverse, we look at the 1 month moving average to make a decision. But that kind of situation is quite infrequent during our study.

Here are the periods when we have decided to make a hedge. The moving average charts and the correlation detection chart are in appendix n°020 of this thesis.

Table n°22: Period selection

DATE	Eurodoll	Forward 3	months	Spot price in $	Spot price €	Spot price with FX hedge	FX profit
24/02/2006	1,1878	1,194308	OK	60,87	51,246001	51,24600101	0
26/05/2006	1,2718	1,279225	ALERT	70,11	55,1265922	55,12659223	0
25/08/2006	1,2757	1,282588	ALERT	71,79	56,2749863	56,27498628	0
24/11/2006	1,3088	1,31449	ALERT	60,01	45,8511614	45,85116137	0
23/02/2007	1,3171	1,322013	OK	60,25	45,7444385	45,74443854	0
25/05/2007	1,3451	1,349325	OK	71,61	53,2376775	53,2376775	0
31/08/2007	1,3636	1,367968	ALERT	72,88	53,4467586	53,44675858	0
30/11/2007	1,4703	1,472069	OK	88,97	60,5114602	60,51146025	0
29/02/2008	1,5175	1,512512	ALERT	100,69	66,3525535	66,35255354	0
30/05/2008	1,5541	1,547101	ALERT	127,29	81,9059263	81,90592626	0
29/08/2008	1,4641	1,457257	ALERT	111,76	76,3335838	76,33358377	0
28/11/2008	1,2705	1,269756	OK	51,88	40,8343172	35,60113281	5,23318438
27/02/2009	1,2716	1,271242	ALERT	45,11	35,4749921	35,47499214	0
29/05/2009	1,4119	1,410871	OK	65,13	46,1293293	46,12932927	0
28/08/2009	1,4328	1,432765	OK	72,84	50,8375209	50,83752094	0
27/11/2009	1,4961	1,49558	ALERT	76,81	51,3401511	51,34015106	0
26/02/2010	1,3602	1,360014	ALERT	76,88	56,5210998	56,52109984	0
28/05/2010	1,2326	1,233872	ALERT	73,01	59,2325166	53,68327091	5,54924572
27/08/2010	1,2746	1,27436	OK	77,31	60,6543229	62,65641817	-2,00209524
26/11/2010	1,3245	1,3239	OK	86,01	64,9377123	64,93771234	0
25/02/2011	1,376	1,374341	ALERT	112,29	81,6061047	81,60610465	0
27/05/2011	1,4319	1,42864	OK	115,99	81,0042601	81,00426007	0
26/08/2011	1,4475	1,445948	ALERT	113,4	78,3419689	78,34196891	0
25/11/2011	1,3241	1,325755	ALERT	107,32	81,0512801	74,22120298	6,83007714
24/02/2012	1,3463	1,346884	ALERT	128,1	95,1496695	96,62418773	-1,47451826
25/05/2012	1,2515	1,252302	OK	108,75	86,8957251	80,74191987	6,15380526
31/08/2012	1,2571	1,258459	OK	115,86	92,1645056	92,16450561	0
30/11/2012	1,3002	1,301397	ALERT	113,11	86,9943086	86,99430857	0
						Sum	20,289699
						Average profit if hedge	3,3816165

Source Excel, Data from bloomberg

The interpretation of the fourth column is as follow:

L) OK means that we are in a high correlation period: no hedge

M) Blue ALERT: we are in a low correlation period but there is an upward trend or equivalent: no hedge

N) Red ALERT: the correlation is low and the trend downward : Hedge

You can see that we make a hedge during 6 out of our 28 trimesters. 4 of those 6 periods were important decreases of the exchange rate. We succeed to hedge during 4 important falls. We also made a hedge during 2 increases but they are quite small. We also miss some decreases but this can be explained by our assumption: we decide to hedge or not only in the beginning of the trimester. If we had considered a more dynamical strategy we would not have missed them.

Table n°23: results improved FX hedge

Performance				
Variance no hedge				0,003282
Variance improved hedge				0,001468
Variance indicator				55%
Average barrel price without hedge				64,36136
Average barrel price with hedge				63,38969

Source: Excel, Data from Bloomberg

Firstly: we can observe that we reduce the variance by 55%. This is positive because we reduce an important part of the total variance by making only 6 hedges on 28 periods.

Secondly: The average price of the barrel is 1€ cheaper only thanks to our currency hedge. This represents a "profit" of 1/64.36= 1.6% during our 28 trimesters.

Thirdly, on the table n°22, if we only consider the 6 period in which we are hedged, our strategy permits to make a total profit of 20.2897 € (the sum of the column "fx profit") during our six periods thanks to our currency hedge. This represents a profit of 20.2897€/6=3.3816€ per barrel per period of hedge. If seems quite useless but a reduction of 5% of the price is not peanut when you have to buy millions of barrels.

In conclusion, this improved hedge permits to obtain an important reduction of variance and to make profits. It is why we decide to use it in our simulation.

4) *Conclusion*

In conclusion we have found in this part that the most sophisticated hedging techniques for commodities do not seem to work better than the naïve ones on a long term point of view. Therefore we decide to dismiss the GARCH techniques for our simulations. We have also seen that the strategies which play with the term structure of the futures prices curves seem to give better results than the other ones. So we select the naïve hybrid strategy to make our simulations because it is the cheapest to implement and the most effective in comparison with the other strategies we have analyzed.

For the currency risk we have shown you that two simple indicators as a correlation indicator and a moving average can reduce the majority of the variance of the sample but also bring profit. This is a simple and efficient way to create a currency hedge.

In the last step of this thesis we will develop a simulation with realistic assumptions. We try to make a kind of backtesting. We will do this simulation with two sets of data to make a robustness test. Those simulations are very useful to present you the combination of our two hedges.

d) Third step: Simulation

This step is the last one in our thesis. We have compared and selected the best strategies to cover our commodity and our currency risk. Now, it is time to study those risks together by using all we have seen previously. And we will make the calculations in a more realistic situation which takes the transactions costs and other indicators into account.

We will make two simulations: one with the same data and another one with another sample. We have not enough time to make all our study on another commodity or another currency but we select other trimesters to compensate this weakness and to check if our strategies work in other conditions.

The principle of our simulation is as follow: in the beginning of each trimester we will go through all the elements to make our decision. Do we have to add a currency hedge to our commodity hedge? Do we have to use CO4 or CO24 contracts? We will include other indicators as momentum and backwardation indicators to make the right decisions. We will first explain those indicators and after that we will explain the results of our two simulations. The calculations are available in the excel file called “Simulations_Benjamin_Brine.xls” on the attached CD.

1) *Indicators*

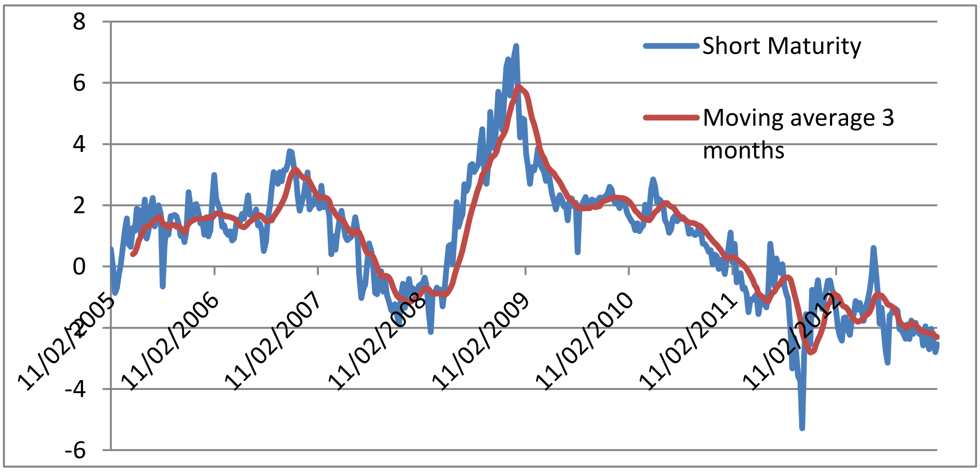
We decide to use two indicators to improve our commodity hedge. Firstly because we want to detect the long term changes of the futures term structure and secondly because it is costly to use a hedge with futures when the prices fall. It is why we use a Backwardation indicator and a momentum indicator.

A) Backwardation indicator

This is the slope of the curve of the futures prices. We subtract the CO1 price from the CO4 price (The short maturity indicator). When this difference is positive it means that we are in Contango. When the difference is negative, we are in Backwardation.

In our comparison of hedges we have all the data and we observe the market situation and we know if the situation happened during the trimester of our hedge. But in a real situation it is impossible to see if the market will stay in Contango or Backwardation. To detect the trend we make the moving average of the short maturity signal. We choose a moving average of 3 months because this is the length of our hedges. So when you decide to hedge, you look at this moving average and you decide to hedge your position with CO4 or CO24 contracts. The moving average gives more indications about a long term trend in the futures market than the simple difference CO4-CO1.

Figure n°16: Moving average backwardation indicator



Source: Excel, Data from Bloomberg

B) Momentum indicator

As we have decided to use a hedge with futures contracts, a momentum indicator seems adequate. Indeed, in case of a fall of the prices, hedging with futures contracts does not allow you to make profits from this price decrease as a hedge with options. We want to take those effects into account. Our objective is not to detect all the price decreases but only the biggest ones.

To do so, we develop an indicator which takes the most important falls of prices into account but which does not take the falls of one or two weeks. It would lead to a too sensitive indicator. It is why we select a momentum indicator of 3 weeks like this to detect the most important changes:

$$Momentum = Spot\ price_{week_i} - Spot\ price_{week_{i-3}}$$

After having selected out a momentum of 3 weeks, we want to detect the trend to avoid some volatility of the prices. Indeed we want to detect a terrible downward trend and not a period of important volatility because this volatility will be automatically killed by our hedge. It is why we make a moving average of 6 weeks on our momentum. We have chosen this value because it gives the best results. The is an arbitrary choice but we have to choose a value.

The next problem is to decide when this moving average of the momentum indicates an abnormal fall. To do this, we suppose that the yearly distribution of our our moving average is normally distributed. Maybe it is not true but we do this only to obtain an "extreme value". To do this we worked out the average and the standard deviation of the value of our moving average during the previous year. With those values we have found the value of the 7.5th percentile of the distribution (z=1.4395). We select 7.5 because it is the value which gives the best results during our empirical study between the values 5, 7.5,10 and 15. And so our extreme value is:

$$Extreme\ value_i = Average_i - 1.4395 * \sigma_i$$

Where:

-$Average_i$= the yearly historical average of the moving average of the momentum for the week i

-σ_i is the yearly historical standard deviation of the moving average of the momentum for the week i.

Once our moving average becomes lower than this extreme value during two consecutive weeks, we consider that we are in an extreme fall of the prices. We do not have to make a hedge on our commodity.

In conclusion it seems in our results that this indicator detects the beginnings of the falls of prices. We use it during our simulation. We will now explain the results of our simulations.

2) *First simulation*

A) Data used

We do this simulation with the same data as used for our comparison. We will first explain the commodity hedge on which we add a momentum indicator. After that we will address the currency hedge and we will finish with our total hedge. We will use the same indicator as for our comparison.

B) Commodity

We begin with the commodity hedge. The only difference is that we add a momentum indicator. This momentum indicator tells us that we do not have to make a hedge during 3 out of our 28 trimesters.

The Backwardation indicator detects 9 trimesters of backwardation and 16 of Contango. We use the same indicators of performances as for our comparison.

It is mentioned in the literature[80] that the transactions cost are between 0.0004% and 0.033%. We choose a value of 0.001% in our study.

We use the Hybrid strategy but we also apply the CO4 and CO24 strategies to see if the results are quite the same as in our comparison. And here are the results.

Table n°24: Results First simulation commodity hedge

Performance	***Hybrid***	***CO4***	***CO24***
Variance Unhedged	0,034196	0,034196	0,034196
Variance Hedged	0,013919	0,012535	0,014974
Variance indicator	59,29%	63,34%	56,21%
Average variation	-1,59564	-1,54158	-1,84516
Minimal variation	-59,8181	-59,8234	-59,8157
Maximal variation	8,639837	5,457201	8,572989

Source: Excel, Data from Bloomberg

The hybrid strategy is a compromise between the variance reduction and the average price of the barrel. It is normal to have a smaller difference on the average variation because we add a momentum indicator and that has a direct impact on that average. Indeed, each minimal variation is equal to -59.8$ and it leads to a smaller average.

C) <u>Currency</u>

We make exactly the same hedge as explained in the comparison. When we are in a low correlation period and when the moving average of the Euro Dollar exchange rate indicates a downward trend, we make a hedge. The charts are available in appendix n°020. Otherwise we do nothing.

[80] J Miffre and G. Rallis, "Momentum Strategies in Commodity Futures Markets", Cass Business School, 2006

As for the comparison, we made 6 FX hedges. And the results are the same:

Table n°23: results improved FX hedge

Performance	
Variance no hedge	0,003282
Variance improved hedge	0,001468
Variance indicator	55%
Average barrel price without hedge	64,36136
Average barrel price with hedge	63,38969

Source: Excel, Data from Bloomberg

D) <u>Two risks</u>

It is now interesting to see how our commodity and currency hedges work together. We analyze different variance indicators and average variations. We also include averages of prices. We analyze different situations: the prices in Euro with no hedge, the prices in Euro with a currency hedge (FX hedge), the prices in Euro with a commodity hedge (Commo hedge) and the prices in Euro with the two hedges (FX + commo hedge). We do all our calculations only with the Hybrid Hedge.

Table n°25: Results first simulation

Performance	***No hedge***	***FX Hedge***	***Commo Hedge***	***FX+ Commo hedge***
Variance Unhedged	0,022711	0,022711	0,022711002	0,022711002
Variance Hedged	0,022711	0,0267606	0,013116118	0,01354821
Variance Indicator	0%	-18%	42%	40%
Average variation	1,3240114	0,3381623	-1,001572047	-2,065676469
Minimal variation	-35,49927	-40,73245	-35,45055823	-40,68998491
Maximal variation	16,668392	16,668392	8,731788525	6,415738212
Average price	64,114319	63,163678	61,53623751	60,51013682

Source: Excel, Data from Bloomberg

The results are very interesting. As you can see, a commodity hedge alone reduces more the variance than the other hedges. This is important but this is not our main objective. Moreover, a currency hedge increases the variance of your prices by 18% but it is not surprising. Indeed, the reduction of variance is less important than in the part about the comparison because we include a momentum indicator. We are not hedged during the most important decreases of prices.

In terms of average variations of prices, the results are also very interesting. All our hedges permit to obtain a cheaper barrel on each trade. But the Commodity+ the FX hedge performs quite better. This hedge permits to have a cheaper barrel by 3.5€ and a variance reduced by 40 %.

3) Second simulation

A) Data used

We want to try our hedge on another sample of data. But it is impossible because we use all our data about the Brent in our study. To make another simulation, we use other trimesters in the same sample. Instead of beginning our analysis the 24/02/2006, we begin the 15/04/2005. We also have 32 instead of 28 trimesters. We have obtained other prices to make another simulation.

As previously, we begin with the commodity hedge and we will analyze the currency hedge after that point. We finish with the two risks.

B) Commodity

We do not explain our different hedges and our indicators again. Here are the results. We detect 2 trimesters in which we do not have to make a hedge, 11 backwardated trimesters and 19 contangoed ones.

Table n°26: Results commodity hedge 2nd simulation

Performance	Hybrid	CO4	CO24
Variance Unhedged	0,034788	0,034788	0,034788
Variance Hedged	0,009806	0,008691	0,011901
Variance indicator	71,81%	75,02%	65,79%
Average variation	-1,29374	-0,59396	-1,40913
Minimal variation	-32,7986	-32,8127	-32,8045
Maximal variation	8,898783	10,98997	15,27379

Source: Excel, Data from Bloomberg

As in the simulation 1, the Hybrid strategy is like a compromise between CO4 and CO24 contracts. The Average variation is smaller because of the momentum indicator.

C) Currency

We have detected 6 trimesters in which there were a currency risk. And here are the results.

Table n°27: Results FX hedge 2nd simulation

Variance no hedge		0,003149217
Variance hedge		0,002271706
Variance indicator		0,278644021
Average barrel price without hedge		62,55034693
Average barrel price with hedge		61,9593231

Source Excel, Data from Bloomberg

Our strategy permits to reduce the variance of the sample and to obtain a higher average of the exchange rate.

D) Two risks

And now, the two hedges together. We do our analysis with the hybrid commodity hedge. All the values are in Euro.

Table n°28: Results second simulation

Performance	No hedge	FX Hedge	Commo Hedge	FX+ Commo hedge
Variance Unhedged	0,029178126	0,029178126	0,029178126	0,029178126
Variance Hedged	0,029178126	0,034101892	0,011921598	0,010844973
Variance Indicator	0%	-17%	59%	63%
Average variation	1,459365174	0,849276061	-0,724108389	-1,9951929
Minimal variation	-34,1176987	-42,5838269	-24,39936452	-36,33176207
Maximal variation	22,6132199	22,6132199	8,481755994	7,599133237
Average price	62,55034693	61,9593231	60,43510691	59,56497021

Source Excel, Data from Bloomberg

The results are also very interesting. The FX hedge does not work to reduce the variance, but reduces the average price variation in comparison with no hedge. The commodity hedge works to reduce our two indicators. The commodity + currency hedge works quite well to reduce the variance and the average variation.

4) *Conclusion and summary*

To conclude this part, we make a summary of our results. Our two simulations give the same results. The FX hedge does not work to reduce the variance, but we can obtain a cheaper barrel. The commodity hedge works quite well in the two performances we have measured. But the combination of the two hedges gives the best results. We can reduce the variance but also pay, on average, a cheaper barrel on each trade.

The reductions of variance are less important than in the comparison because we are not hedged during important decreases of prices.

To play with the maturity of the futures gives interesting results. We can still reduce the variance but with getting, on average, a cheaper barrel. This strategy is a very good compromise between a strategy of reduction of variance and a strategy which brings profits.

We can complete the piece of advice given in the BNP Paribas Riskbook we have read in the beginning of our internship. Adding a currency hedge to the commodity hedge allows to reduce the variance and allows to pay a cheaper barrel too. It is better to use the two hedges together than only one. But it is still better to make only one hedge than to make nothing at all.

V) Conclusion

Now it is time to conclude our project. We reach our objective of providing an efficient hedging strategy with the two risks. We will shortly come back to the major theoretical elements we have seen together. After that we will speak about the practical elements and we will finish with the points to develop.

We have seen together the elements which have an impact on the oil price but also the elements which influence the value of the correlation between the Brent oil price and the Euro Dollar exchange rate. We have also seen some statistical methods like linear regressions, GARCH and PCA and how to use them on a financial issue. And last but not least, we have gathered a lot of information about the Backwardation and the Contango term structures, what influences those effects and the impacts on the profitability of a hedging strategy. Indeed, the futures contracts to use are not the same in case of an important change in the slope of the futures prices curve.

Practically we obtain interesting results in our different steps. We have obtained an indicator which can be used with different purposes. Indeed, even if we study the correlation between the oil price and the Euro Dollar exchange rate, we have observed that were able to detect the future important variations of the exchange rate. So this indicator could be used with other commodities to detect the changes of the exchange rate and to identify the risks on which we have to make a hedge. We think that it is a real advantage for the Bank.

We have also seen that it is really interesting and important to work with the futures prices term structure to obtain a cheap an effective strategy. We have also seen that the basic approach gives quite the same results as the most sophisticated techniques like GARCH OHR. We have detected an important trend in our results. If you want to reduce the volatility of the prices, you have to select the futures contract with the nearest maturity because this is the most correlated with the spot price. On the contrary, the contracts with a more important maturity can bring you profits on average. A hybrid strategy which plays with those maturities can be a good compromise between those benefits. Indeed you can obtain an important reduction of the volatility and also take benefits, on average, from a move in the futures prices terms structure. Those observations are also confirmed in our two simulations with different prices.

We have also succeeded in determining that it is not better to always make a full hedge on our commodity and currency risk or to do nothing as advised in the BNP Paribas Riskbook. It is better to study the patterns of correlation between the variables and to determine when you have to create a currency hedge or not. This is cheaper and it brings more profits to the client. We have done this with only some moving average indicators and some PCA.

We know that we have had some problems to implement our conditional strategies. However, according to the literature that kind of strategy does not perform so well on long term but we were not able to test if it is really true. It is a point which can be developed in a future work. Moreover we do not have time enough to work with another sample of data to create a full backtesting. Our results could be confirmed with another commodity. It would be interesting to develop those points in another master thesis.

This master thesis develops quite well the hedging strategies with futures contracts. However it could be interesting to develop other strategies with other derivatives as swaps, collar, and other options to have a wider analysis.

Finally, we have also learnt a lot on a personal point of view from this project. We learnt how to use SAS, statistical methods and also financial theories. It was very interesting to make a complete project with the elements we have seen during our studies.

Our internship was also very interesting for some elements: we discover how was working the financial world and how to be organized for a project like this. Indeed this master thesis is the achievement of a work which began in Augustus 2012 and we hope that it was really interesting for you as it was for us.

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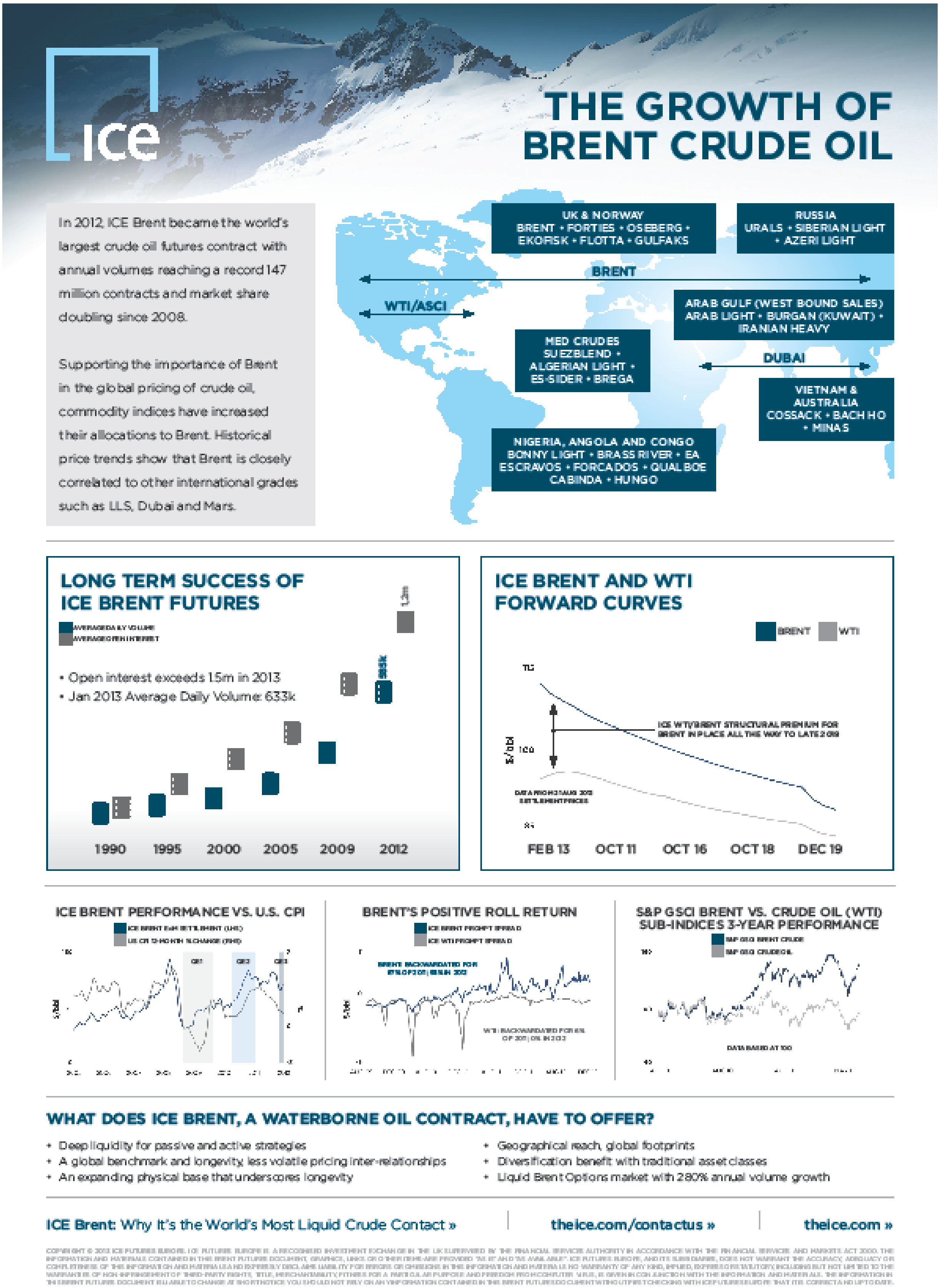
Appendices

List of the appendices:

Appendix n° 001: Information about the Brent oil



Source: ICE intercontinental exchange, <https://www.theice.com/homepage.jhtml>, page accessed the 3rd March 2013.

Appendix n° 002: PCA example on SAS

1) *Factors*

Here is an example given by the SAS website[81]: PCA is used on five variables (population, school, employment, services, house value) which all have 12 observations.

The first result that SAS gives is as follow:

Eigenvalues of the Correlation Matrix: Total = 5 Average = 1				
	Eigenvalue	**Difference**	**Proportion**	**Cumulative**
1	2.87331359	1.07665350	0.5747	0.5747
2	1.79666009	1.58182321	0.3593	0.9340
3	0.21483689	0.11490283	0.0430	0.9770
4	0.09993405	0.08467868	0.0200	0.9969
5	0.01525537		0.0031	1.0000

Source: SAS, <http://support.sas.com/documentation/cdl/en/statug/63347/HTML/default/viewer.htm#statug_factor_sect028.htm>, IT Support, page accessed the 3rd February 2013.

You can see that SAS extracts 5 factors from the sample (The same number as the number of variables, it is normal). The cumulative value of the two first factors' proportion is equal to 0.9340. It means that 93.40% of the sample's variance is explained by those two factors. In this case, it is enough; so we retain the two first factors and "forget" the other ones for the rotation.

After that we analyze another output from SAS which permits to work out the values of our factors: the unrotated standardized scoring coefficients or the weight w_{ij} we explained in the practical part which are important to work out the value of the factors:

[81] SAS, <http://support.sas.com/documentation/cdl/en/statug/63347/HTML/default/viewer.htm#statug_factor_sect028.htm>, IT Support, page accessed the 3rd February 2013.

	Factor1	Factor2	Factor3	Factor4	Factor5
Population	0.20219065	0.44884459	0.1284067	0.64542101	5.58240225
School	0.26695219	-0.3032049	1.48611655	-1.1184573	1.41573501
Employment	0.23402646	0.40410834	0.53496241	0.07255759	-5.6513542
Services	0.32450082	-0.0580552	-1.432726	-1.5828806	-0.0010006
HouseValue	0.27534803	-0.3106762	-0.3012889	2.41418899	-0.6673445

After the standardized scoring coefficient, we analyze the rotated factors patterns (or loadings) to allow interpretation and to obtain the value of our two orthogonal factors as follow:

	Factor1	Factor2
HouseValue	0.94072	-0.00004
School	0.90419	0.00055
Services	0.79085	0.41509
Population	0.02255	0.98874
Employment	0.14625	0.97499

Those values tell us essentially two things: firstly they are helpful to represent the variables (one row per variable), secondly, they indicate the correlation between the factor and the variables. So if the value of the rotated factor pattern of a determined variable is near 1 or -1 it indicates a strong correlation (positive or negative) between this factor and the variable.[82] The variable is very important in the explanation of the factor and if the factor explains an important proportion of the variance, it means that the variable is very important to explain the variance of the sample. We use this principle in our practical part.

[82] SAS, <http://support.sas.com/documentation/cdl/en/statug/63347/HTML/default/viewer.htm#statug_factor_sect028.htm>, IT Support, page accessed the 3rd February 2013.

2) Performance measures

In our example, SAS gives us this table:

Table n°05: KMO's

Kaiser's Measure of Sampling Adequacy: Overall MSA = 0.57536759

Population	**School**	**Employment**	**Services**	**HouseValue**
0.47207897	0.55158839	0.48851137	0.80664365	0.61281377

In our example, MSA is equal to 0.57. It's not an important value but it is still acceptable.

Appendix n° 003: The Black Scholes and Merton Model

The Black Scholes-Merton model is based on some assumptions[83]:

- The return and the volatility follow a stochastic model
- There is no restriction on short selling. The result of those operations is immediately and fully available.
- There is no tax or transaction costs. All the financial assets are perfectly divisible.
- The underlying asset gives no dividend during the life of the option.
- There is no arbitrage possibility.
- The market work continuously
- The risk-free rate "r" is constant and fixed whatever the maturity of the derivative.

The Black Scholes-Merton equations are as follow[84]:

$$d1 = \frac{\ln\left(\frac{S_0}{\mathrm{K}}\right) + \left(\mathrm{r} + \frac{\sigma^2}{2}\right) * T}{\sigma\sqrt{T}}$$

$$d2 = d1 - \sigma\sqrt{T}$$

$$\mathrm{c} = S_0 N(d1) - Ke^{-rT}N(d2)$$

$$p = Ke^{-rT}N(-d2) - S_0 N(-d1)$$

Where:

-S_0 : the price of the underlying asset

-K: the strike price of the option

-r: the risk free rate

-σ: the historical volatility[85]

-T: the maturity of the option

-c= the call price

-p: the put price

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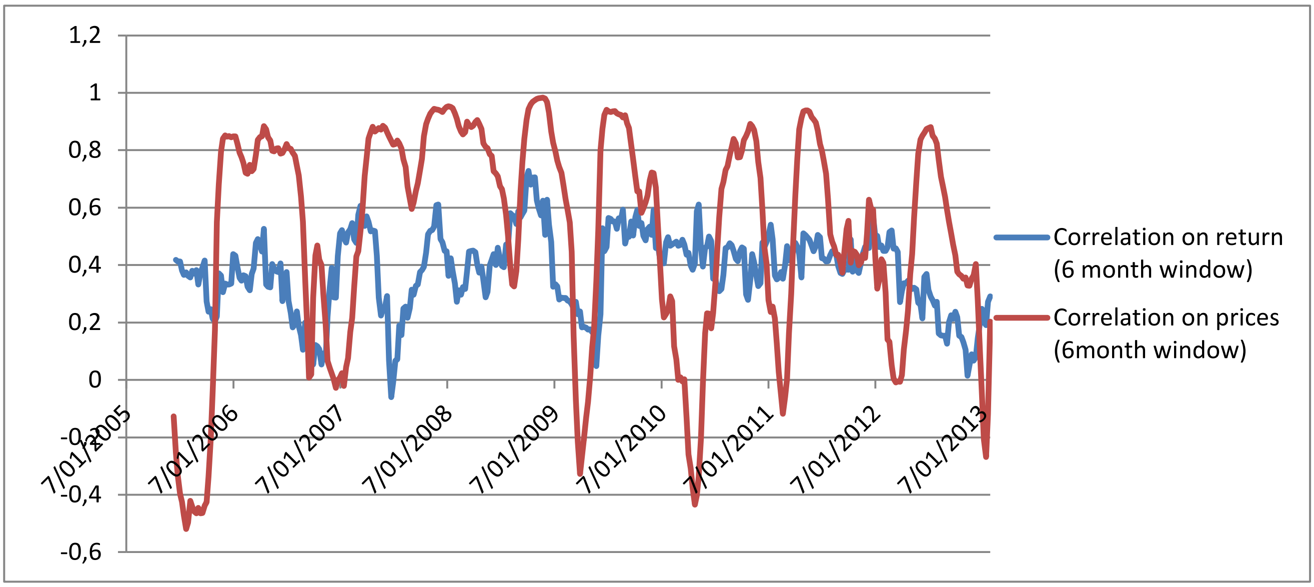
[83] J. Hull, « Options, Futures and other derivatives », New Jersey, Pearson, 8th edition, 2011.
[84] ibidem
[85] We can use the historical volatility and not only the implied volatility. Source: J. Hull, « Options, Futures and other derivatives », New Jersey, Pearson, 8th edition, 2011.

Appendix n°004: charts for the correlation analysis

Data from Bloomberg



The gaps of correlation are less obvious with the returns.

The level of correlation is in the y axis. The x axis represents the dates.

Appendix n° 005: explanations of the selected variables

Monetary Variables

1) France Inflation: The Crude oil is a very important asset of the economy, so there is no doubt a link between the evolution of the prices and the oil price. A good approximation of the expected inflation is the break-even rate. We work out this break-even rate by subtracting the real interest yield from the nominal interest yield. We used two French bonds of 20 years each. If we follow the formula, we obtain the expected the break even rate or the expected inflation rate in France.

Break even rate = Nominal rate – inflation linked rate

2) US Inflation: We obtain the inflation rate in the US in the same way. We use two bonds of the US government with 20 years maturities.

3) 1 year Franch SWAP rate: This is the rate to pay if you want to be protected against the inflation in one year. We include it to have a good measure of the expected inflation in one year in france.

4) Swap rate curve in France: The expected evolution of the inflation for the next years in France can be observed in the curve of the inflation swap rate. To obtain this curve, we subtracted the 1-year inflation swap rate from the 5-year inflation swap rate. We were unable to do this for the US because the dates did not match the other variables (monthly data's). The impact of this variable seems very important to us even if we only had the European one. Indeed, an important curve means that the inflation is expected to increase.

5) And 6) Euribor and Libor: those rates are the interbank rates; it is the yield at which they exchange money to each other. They are very important to reflect the risk in the bank and financial sectors in the US and in Europe. The higher this rate the higher is the risk in the bank sector. Indeed we observed an increase during the sample 2007-2009.

7) Spread of the European companies: this spread is very useful to reflect the health of the professional sector in Europe. This is the difference between the average yield of BBB rated companies' bond and the German government bond interest rate. The more important this spread, the more important is the risk in the professional sector. This variable helps us to reflect the professional sector effect in the economy.

8) Spread of the US companies: We did the same for the US. We take bonds from BBB companies and a bond of the US government, which has no important risk.

9) EUSA Slope (nominal interest rates): to detect if the slope of the interest rates curve is relevant in our analysis, we worked out the five year interest rate minus the two year interest rates. If the slope is positive, we expect an increase in the interest rates.

10) US Rate slope (nominal interest rates): We do the same for the United States to detect the impact of the evolution of the interest rates on the Brent crude oil price.

11) EUSA forward rate 5 years in 3 months: We select this variable to reflect the interest rate in Europe. There may be a link between the Brent crude oil price and the forward interest rate. This variable was included in our analysis to reflect the level of the forward interest rates. There is an important link between our forward and our spot EUSA rates, but the Principal component analysis will help us to remove this important correlation.

12) EUSA Forward rates slope: we select this variable to input the forward rates curve in our analysis. We make the difference between the EUSA forward 5 years in 5 years and the EUSA forward Price 5 years in 3 months. We make this to detect if there is a link between the slope of the forward rate curve and the correlation.

Foreign exchange Variables (forex or FX variables)

13) Euro-Dollar Exchange Rate: The Brent Oil is extracted in Europe but is usually traded in dollar. This exchange rate has to have an impact on the Brent crude oil commodity price in dollar itself before having directly an impact on the Brent price in Euro. This is a central point in our master thesis.

14) Euro-Yen exchange rate: Japan's economy is one of the most important in the world. Therefore, we decided to include this variable in our model.

15) Euro-rouble exchange rate: Russia is an important oil producer; we want to reflect this in our study by including this exchange rate. It's a good way to take the Russian economy into account in our analysis.

16) Asian, Dollar, Yen, and Euro Trade Weighted Index (TWI). Those indexes measure the power of a currency. Those 3 variables are aggregated on a particular way: the higher this index the more used is the currency in the economy. To have more details on those indexes, see thefederal reserve website[86]. Those TWI are very helpful to get a measure of the level of the currencies. The ASIAN TWI was introduced to have a variable which represents the performance of some currencies of Asian countries.

"Real" Economy variables

17) S&P500 and Eurostoxx: those indexes are very important to detect the performances and the stock values of the main companies in Europe and in the US. It is so a good summary of the economic activity.

18) The Hang Seng Index (HIS) and the Bovespa Brasil Stock Exchange Index (IBOV). Those two variables were included to reflect the emergent countries economics' performances on the Oil spot price. HSI was selected to reflect the Chinese economy and IBOV for the Brazilian one, two important emerging countries.We read in nearly all the studies that emerging countries have an impact on the fuel price because they consume a lot of fuel to support their growth[87]. We included them to see if it was true.

19) The Copper price and the Goldman Sachs Commodity index on industrial metals (GSCI). The industry and the industrial production are linked with the health of the economy. Moreover, a good industrial production could mean a good industrial health. It is why we wanted to

[86] Federal Reserve, "Indexes of the Foreign Exchange Value of the Dollar", <http://www.federalreserve.gov/pubs/bulletin/2005/winter05_index.pdf>, page accessed the 26th February 2013
[87] BNP Paribas, "Commodity Market: Oil outlook 2013 and beyond", presentation, 2013.

include some “industrial” variables in our study. We selected some metal prices because they are a significant part of the industrial raw materials consumption in the developed countries.

20) The gold price: gold is an important indicator of the economy. People could buy gold when they worry about the economy and they buy gold because it is a heaven asset. This variable could have been put in the stress variables category but we rather put it in the Real Economy category because it is a “real” asset.

21) Department Of Energy, Total Change in Crude Oil: We read in many studies[88][89] that the US petroleum reserves were a determinant factor of the oil price. We decided to consider this variable in our analysis. The Department Of Energy of the United States publishes the oil inventory level of the United States each Friday.

22) Spread WTI price – Brent blend Oil Price: The difference between the two most important oil assets could be also meaningful in our analysis. When one is too high, an arbitrage relationship could emerge from this disequilibrium and explain some Brent Crude oil price fluctuation.

<u>Stress variables</u>

23) The Chicago Board Options Exchange Market Volatility Index (VIX) is a good measure for the stress on the stock market. The VIX indicates the implied short-term volatility on the S&P500 index. The higher this index, the higher is the stress on the market. More information on VIX index is available on the Chigaco Board Option Exchange website[90].

24) The liquidity of the Bank sector in US and in Europe. Those indicators are included to show the stress in the Bank sector through liquidity. It is constructed by subtracting a risk free bond from the interbank rates (Euribor and libor). In our case, the risk free bonds are a 3 month maturity bonds of the US and German governments. When this spread is high, the banks are more reticent to exchange money between them, so it means less liquidity and more stress on the marke

[88] P. Artus, «Flash Marchés : Y-a-t-il vraiment un lien entre le prix du pétrole et le taux de change du dollar ? », Natixis, n°98, 2008
[89] A. Dieudonné, « Modélisation du prix du pétrole », FUNDP ; mémoire de fin d’études, 2006.
[90] CBOE, “Volatility Index at CBOE”, http://www.cboe.com/micro/VIX/pdf/VolatilityIndexQRG2012-01-30.pdf, pdf online, page accessed the 1st March 2013.

Appendix n°006: PCA of the Low correlation period n°1

The complete SAS outputs are available on the attached CD.

PCA RESULT
data set
from PROC
SCORE

The FACTOR Procedure

Input Data Type	Raw Data
Number of Records Read	48
Number of Records Used	48
N for Significance Tests	48

Kaiser's Measure of Sampling Adequacy: Overall MSA = 0.73636170

Inflation_France	Inflation_US	Taux_SWAP_inflation_FR_1an	swap_rate_curve	EURIBOR	LIBOR
0.61359543	0.82226477	0.67235785	0.38875216	0.80285575	0.63350268
EUSA_3M05	**SLOPE_FORWARD_EUSA**	**SPREAD_EU_CMPNY**	**SPREAD_US_CMPNY**	**EUSA_SLOPE**	**US_rate_slope**
0.45745079	0.73909467	0.58665310	0.86978776	0.69283983	0.76969242
EURODOLL	**EUROYEN**	**EUROROUBLE**	**ASIAN_TWI**	**EURO_TWI**	**DOLLAR_TWI**
0.68822383	0.81985585	0.67937183	0.82971043	0.84174658	0.46863786
YEN_TWI	**SPREAD_WTIBRENT**	**Var_Oil_RSV**	**SP500**	**Eurostoxx**	**HSI**
0.80312006	0.30827078	0.35515676	0.87843049	0.84052974	0.91654724
IBOV	**GSCI**	**GOLD**	**COPPER**	**VIX**	**Liquidity_EU**
0.75196189	0.53403188	0.58294848	0.62079691	0.81759497	0.61668428
Liquidity_US					
0.75373841					

Prior Communality Estimates: ONE

Eigenvalues of the Correlation Matrix: Total = 31 Average = 1				
	Eigenvalue	**Difference**	**Proportion**	**Cumulative**
1	147.874.911	101.023.504	0.4770	0.4770
2	46.851.407	11.320.796	0.1511	0.6281
3	35.530.611	11.564.637	0.1146	0.7428
4	23.965.974	0.6980871	0.0773	0.8201
5	16.985.102	0.8766581	0.0548	0.8749
6	0.8218521	0.0265802	0.0265	0.9014
7	0.7952719	0.1525797	0.0257	0.9270
8	0.6426923	0.2437844	0.0207	0.9478
9	0.3989079	0.1102178	0.0129	0.9606
10	0.2886900	0.0710585	0.0093	0.9699
11	0.2176315	0.0499000	0.0070	0.9770
12	0.1677315	0.0415176	0.0054	0.9824
13	0.1262139	0.0396930	0.0041	0.9864
14	0.0865209	0.0034614	0.0028	0.9892
15	0.0830594	0.0342940	0.0027	0.9919
16	0.0487654	0.0074049	0.0016	0.9935
17	0.0413605	0.0043678	0.0013	0.9948
18	0.0369927	0.0094648	0.0012	0.9960
19	0.0275279	0.0016959	0.0009	0.9969
20	0.0258319	0.0051518	0.0008	0.9977
21	0.0206801	0.0072230	0.0007	0.9984
22	0.0134571	0.0025636	0.0004	0.9988
23	0.0108936	0.0031714	0.0004	0.9992
24	0.0077222	0.0011503	0.0002	0.9994
25	0.0065719	0.0025366	0.0002	0.9997
26	0.0040353	0.0005817	0.0001	0.9998
27	0.0034535	0.0016184	0.0001	0.9999
28	0.0018351	0.0009902	0.0001	10.000
29	0.0008449	0.0002620	0.0000	10.000
30	0.0005829	0.0005098	0.0000	10.000
31	0.0000731		0.0000	10.000

6 factors will be retained by the MINEIGEN criterion.

Factor Pattern

		Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
HSI	**HSI**	98	2	12	-2	3	9
EURIBOR	**EURIBOR**	96	10	-21	3	-1	9
EUROYEN	**EUROYEN**	96	8	-5	19	5	5
SP500	**SP500**	96	-5	17	-11	-15	4
Eurostoxx	**Eurostoxx**	92	-17	21	-17	-11	7
IBOV	**IBOV**	82	6	52	-11	-5	7
ASIAN_TWI	**ASIAN_TWI**	81	-41	-35	13	2	9
EURO_TWI	**EURO_TWI**	78	54	6	17	-3	-9
EUSA_3M05	**EUSA_3M05**	49	11	39	39	40	48
COPPER	**COPPER**	-57	53	-41	-37	-3	3
Inflation_France	**Inflation_France**	-61	45	20	-4	38	23
Taux_SWAP_inflation_FR_1an	**Taux_SWAP_inflation_FR_1an**	-67	22	34	39	-31	13
Liquidity_US	**Liquidity_US**	-69	17	-33	38	-36	-4
VIX	**VIX**	-73	29	-9	35	22	0
US_rate_slope	**US_rate_slope**	-86	-8	39	-17	3	14
EUSA_SLOPE	**EUSA_SLOPE**	-87	-6	42	7	14	4
Inflation_US	**Inflation_US**	-88	11	30	-9	21	-5
SPREAD_US_CMPNY	**SPREAD_US_CMPNY**	-90	-9	-38	-6	-8	8
YEN_TWI	**YEN_TWI**	-90	28	12	-19	-9	-10
SLOPE_FORWARD_EUSA	**SLOPE_FORWARD_EUSA**	-93	-2	27	3	16	-2
EUROROUBLE	**EUROROUBLE**	32	85	31	-1	-10	-10
EURODOLL	**EURODOLL**	66	72	3	7	-5	-7
GSCI	**GSCI**	32	66	-26	-48	-12	11
GOLD	**GOLD**	17	60	58	-24	35	-1
DOLLAR_TWI	**DOLLAR_TWI**	3	-93	13	17	7	12
LIBOR	**LIBOR**	26	45	-68	31	30	17
SPREAD_EU_CMPNY	**SPREAD_EU_CMPNY**	-47	26	-72	7	4	27
SPREAD_WTI BRENT	**SPREAD_WTI BRENT**	-13	-2	12	67	8	-2
Var_Oil_RSV	**Var_Oil_RSV**	6	-41	9	-48	26	-4
swap_rate_curve	**swap_rate_curve**	14	-21	-51	-37	67	-10
Liquidity_EU	**Liquidity_EU**	-36	-9	4	-48	-44	53

Printed values are multiplied by 100 and rounded to the nearest integer.

Variance Explained by Each Factor					
Factor1	**Factor2**	**Factor3**	**Factor4**	**Factor5**	**Factor6**
14.787.491	4.685.141	3.553.061	2.396.597	1.698.510	0.821852

Rotated Factor pattern

		Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
Inflation_US	**Inflation_US**	97	-1	1	0	-1	1
SLOPE_FORWARD_EUSA	**SLOPE_FORWARD_EUSA**	96	-18	4	-9	-2	-1
EUSA_SLOPE	**EUSA_SLOPE**	94	-20	-9	-15	9	1
US_rate_slope	**US_rate_slope**	91	-18	-11	-7	2	27
YEN_TWI	**YEN_TWI**	89	15	14	-13	-29	16
Inflation_France	**Inflation_France**	75	30	23	3	32	3
VIX	**VIX**	68	2	46	-22	5	-25
SPREAD_US_CMPNY	**SPREAD_US_CMPNY**	66	-31	53	-4	-33	22
EURO_TWI	**EURO_TWI**	-64	64	-11	-15	20	-25
Eurostoxx	**Eurostoxx**	-80	9	-50	15	19	12
HSI	**HSI**	-84	22	-33	12	32	-5
SP500	**SP500**	-84	19	-45	7	17	6
EUROYEN	**EUROYEN**	-88	21	-13	2	30	-20
ASIAN_TWI	**ASIAN_TWI**	-91	-30	2	18	12	-10
EURIBOR	**EURIBOR**	-93	25	-2	12	20	-6
EUROROUBLE	**EUROROUBLE**	-10	91	-16	-25	13	-8
EURODOLL	**EURODOLL**	-51	81	-2	-13	15	-16
GSCI	**GSCI**	-28	75	22	19	-11	35
GOLD	**GOLD**	22	72	-38	17	39	-7
DOLLAR_TWI	**DOLLAR_TWI**	-11	-90	-28	9	15	-2
SPREAD_EU_CMPNY	**SPREAD_EU_CMPNY**	21	0	90	-1	-10	14
LIBOR	**LIBOR**	-37	29	78	6	21	-27
COPPER	**COPPER**	47	42	57	13	-32	28
IBOV	**IBOV**	-57	31	-65	2	35	5
swap_rate_curve	**swap_rate_curve**	-13	-12	32	87	0	-17
Var_Oil_RSV	**Var_Oil_RSV**	3	-23	-28	57	-2	15
Liquidity_US	**Liquidity_US**	42	-12	53	-55	-35	-2
Taux_SWAP_inflation_FR_1an	**Taux_SWAP_inflation_FR_1an**	63	-1	3	-69	5	6
EUSA_3M05	**EUSA_3M05**	-27	9	-15	-9	90	-16
Liquidity_EU	**Liquidity_EU**	24	-10	2	-7	-7	88
SPREAD_WTI BRENT	**SPREAD_WTI BRENT**	12	-20	8	-43	24	-43

Printed values are multiplied by 100 and rounded to the nearest integer.

Variance Explained by Each Factor					
Factor1	**Factor2**	**Factor3**	**Factor4**	**Factor5**	**Factor6**
12.616.252	4.890.726	4.135.441	2.439.482	2.147.374	1.713.378

Appendix n°007: PCA of the High correlation period n°1

The complete SAS outputs are available on the attached CD.

PCA RESULT	
data set from PROC SCORE	
The FACTOR Procedure	
Input Data Type	Raw Data
Number of Records Read	77
Number of Records Used	77
N for Significance Tests	77

Kaiser's Measure of Sampling Adequacy: Overall MSA = 0.83061401						
Inflation_France	**Inflation_US**	**Taux_SWAP_inflation_FR_1an**	**swap_rate_curve**	**EURIBOR**	**LIBOR**	**EUSA_3M05**
0.95129295	0.38399911	0.67213646	0.56755125	0.79094757	0.86855954	0.58423425
SLOPE_FORWARD_EUSA	**SPREAD_EU_CMPNY**	**SPREAD_US_CMPNY**	**EUSA_SLOPE**	**US_rate_slope**	**EURODOLL**	**EUROYEN**
0.64409355	0.84674171	0.86608151	0.74092317	0.91500929	0.84972655	0.65208828
EUROROUBLE	**ASIAN_TWI**	**EURO_TWI**	**DOLLAR_TWI**	**YEN_TWI**	**SPREAD_WTIBRENT**	**Var_Oil_RSV**
0.95063819	0.81593287	0.90428745	0.85352790	0.85412462	0.85475536	0.42123181
SP500	**Eurostoxx**	**HSI**	**IBOV**	**GSCI**	**GOLD**	**COPPER**
0.83595375	0.88794293	0.69242537	0.86186331	0.63179745	0.90301800	0.75381218
VIX	**Liquidity_EU**	**Liquidity_US**				
0.85518774	0.86728678	0.86029720				

Prior Communality Estimates: ONE				
Eigenvalues of the Correlation Matrix: Total = 31 Average = 1				
	Eigenvalue	**Difference**	**Proportion**	**Cumulative**
1	153.827.693	104.516.830	0.4962	0.4962
2	49.310.863	13.422.973	0.1591	0.6553
3	35.887.890	14.192.455	0.1158	0.7711
4	21.695.435	11.991.309	0.0700	0.8410
5	0.9704125	0.0387483	0.0313	0.8723
6	0.9316642	0.1989864	0.0301	0.9024
7	0.7326778	0.0891944	0.0236	0.9260
8	0.6434834	0.1937881	0.0208	0.9468
9	0.4496953	0.0715566	0.0145	0.9613
10	0.3781386	0.1280084	0.0122	0.9735
11	0.2501302	0.0736037	0.0081	0.9816
12	0.1765265	0.0892102	0.0057	0.9873
13	0.0873163	0.0163121	0.0028	0.9901
14	0.0710042	0.0184056	0.0023	0.9924
15	0.0525985	0.0137941	0.0017	0.9941
16	0.0388044	0.0053498	0.0013	0.9953
17	0.0334547	0.0126635	0.0011	0.9964
18	0.0207911	0.0018397	0.0007	0.9971
19	0.0189515	0.0029708	0.0006	0.9977
20	0.0159807	0.0029335	0.0005	0.9982
21	0.0130472	0.0019752	0.0004	0.9986
22	0.0110720	0.0028011	0.0004	0.9990
23	0.0082710	0.0011365	0.0003	0.9992
24	0.0071345	0.0019853	0.0002	0.9995
25	0.0051492	0.0014069	0.0002	0.9996
26	0.0037423	0.0010966	0.0001	0.9997
27	0.0026457	0.0002041	0.0001	0.9998
28	0.0024415	0.0009624	0.0001	0.9999
29	0.0014791	0.0007286	0.0000	10.000
30	0.0007505	0.0003013	0.0000	10.000
31	0.0004492		0.0000	10.000
6 factors will be retained by the MINEIGEN criterion.				

	Factor Pattern						
		Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
SPREAD_US_CMPNY	**SPREAD_US_CMPNY**	98	-12	-7	-5	-1	5
EURODOLL	**EURODOLL**	98	9	-4	11	-4	-3
SPREAD_EU_CMPNY	**SPREAD_EU_CMPNY**	98	-8	-15	-3	-4	4
EUROROUBLE	**EUROROUBLE**	97	5	-7	12	-8	-3
EURO_TWI	**EURO_TWI**	97	17	-8	7	-4	3
GOLD	**GOLD**	94	-15	-10	12	5	-3
US_rate_slope	**US_rate_slope**	94	-14	-21	8	8	4
Inflation_France	**Inflation_France**	86	39	-9	4	12	-2
YEN_TWI	**YEN_TWI**	84	-43	-13	-6	-22	-18
EURIBOR	**EURIBOR**	83	25	39	-11	4	8
IBOV	**IBOV**	77	14	36	36	-5	1
Liquidity_EU	**Liquidity_EU**	76	-3	50	3	-24	6
ASIAN_TWI	**ASIAN_TWI**	71	36	-39	-34	8	15
VIX	**VIX**	62	-40	22	-20	40	-16
SPREAD_WTIBRENT	**SPREAD_WTIBRENT**	58	-32	49	4	10	2
EUSA_SLOPE	**EUSA_SLOPE**	-60	-56	2	19	37	18
SP500	**SP500**	-74	13	50	33	-10	12
Eurostoxx	**Eurostoxx**	-81	0	49	25	-6	8
LIBOR	**LIBOR**	-91	2	37	-3	7	-2
DOLLAR_TWI	**DOLLAR_TWI**	-95	4	-19	-21	-6	2
EUSA_3M05	**EUSA_3M05**	1	91	1	-8	30	12
Taux_SWAP_inflation_FR_1an	**Taux_SWAP_inflation_FR_1an**	30	85	16	-16	-11	-3
EUROYEN	**EUROYEN**	11	83	11	23	30	28
swap_rate_curve	**swap_rate_curve**	27	-70	-30	-10	34	13
SLOPE_FORWARD_EUSA	**SLOPE_FORWARD_EUSA**	23	-88	12	25	-2	9
HSI	**HSI**	35	-6	83	27	5	11
Liquidity_US	**Liquidity_US**	55	-22	65	-6	2	6
GSCI	**GSCI**	-30	6	-49	72	-19	-6
Inflation_US	**Inflation_US**	-14	14	-24	63	35	-38
COPPER	**COPPER**	52	20	-30	63	-5	5
Var_Oil_RSV	**Var_Oil_RSV**	-3	-25	-44	13	-11	70
	Printed values are multiplied by 100 and rounded to the nearest integer.						

Variance Explained by Each Factor					
Factor1	**Factor2**	**Factor3**	**Factor4**	**Factor5**	**Factor6**
15.382.769	4.931.086	3.588.789	2.169.543	0.970413	0.931664

	Rotated Factor Pattern						
		Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
SPREAD_EU_CMPNY	SPREAD_EU_CMPNY	94	31	-6	-5	0	6
US_rate_slope	US_rate_slope	91	29	-9	8	13	9
SPREAD_US_CMPNY	SPREAD_US_CMPNY	91	38	-7	-9	4	5
EURO_TWI	EURO_TWI	90	36	18	5	-8	3
EUROROUBLE	EUROROUBLE	90	39	4	9	-10	1
EURODOLL	EURODOLL	89	42	9	8	-7	-2
GOLD	GOLD	87	38	-12	10	9	1
ASIAN_TWI	ASIAN_TWI	83	-12	40	-24	6	10
YEN_TWI	YEN_TWI	82	26	-47	-8	-10	-9
Inflation_France	Inflation_France	81	27	42	8	2	-7
EUSA_SLOPE	EUSA_SLOPE	-60	-9	-44	15	50	23
DOLLAR_TWI	DOLLAR_TWI	-75	-64	-1	-11	-4	4
SP500	SP500	-91	18	12	17	-19	7
Eurostoxx	Eurostoxx	-96	13	0	12	-10	3
LIBOR	LIBOR	-97	-11	4	-7	4	-11
HSI	HSI	-8	94	4	0	1	-5
Liquidity_US	Liquidity_US	22	80	-12	-27	6	-11
Liquidity_EU	Liquidity_EU	46	76	-1	-18	-24	-5
IBOV	IBOV	51	73	16	21	-14	-2
SPREAD_WTIBRENT	SPREAD_WTIBRENT	30	71	-21	-13	15	-8
EURIBOR	EURIBOR	59	64	33	-22	-3	-9
EUSA_3M05	EUSA_3M05	2	-9	96	3	6	-5
EUROYEN	EUROYEN	2	17	91	24	7	15
Taux_SWAP_inflation_FR_1an	Taux_SWAP_inflation_FR_1an	23	12	81	-13	-32	-19
swap_rate_curve	swap_rate_curve	35	-5	-56	-8	56	20
SLOPE_FORWARD_EUSA	SLOPE_FORWARD_EUSA	11	38	-82	8	19	20
Inflation_US	Inflation_US	-6	-13	8	80	20	-22
GSCI	GSCI	-12	-35	-10	79	-25	24
COPPER	COPPER	53	15	14	63	-14	23
VIX	VIX	47	43	-26	-20	48	-27
Var_Oil_RSV	Var_Oil_RSV	10	-21	-18	2	6	83
Printed values are multiplied by 100 and rounded to the nearest integer.							

Variance Explained by Each Factor					
Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
13.017.484	5.718.142	4.554.050	2.200.698	1.278.356	1.205.535

Appendix n°008: PCA of the low correlation period n°2

The complete SAS outputs are available on the attached CD.

PCA RESULT	
data set from PROC SCORE	
The FACTOR Procedure	
Input Data Type	Raw Data
Number of Records Read	51
Number of Records Used	51
N for Significance Tests	51

Kaiser's Measure of Sampling Adequacy: Overall MSA = 0.77290630						
Inflation_France	**Inflation_US**	**Taux_SWAP_inflation_FR_1an**	**swap_rate_curve**	**EURIBOR**	**LIBOR**	**EUSA_3M05**
0.78801023	0.65603053	0.78316111	0.73651927	0.82967176	0.82337597	0.79074196
SLOPE_FORWARD_EUSA	**SPREAD_EU_CMPNY**	**SPREAD_US_CMPNY**	**EUSA_SLOPE**	**US_rate_slope**	**EURODOLL**	**EUROYEN**
0.78126111	0.80633606	0.85574640	0.79511117	0.86421589	0.71062257	0.74780132
EUROROUBLE	**ASIAN_TWI**	**EURO_TWI**	**DOLLAR_TWI**	**YEN_TWI**	**SPREAD_WTIBRENT**	**Var_Oil_RSV**
0.84038508	0.83898135	0.85491775	0.71346898	0.70727676	0.31102601	0.58457978
SP500	**Eurostoxx**	**HSI**	**IBOV**	**GSCI**	**GOLD**	**COPPER**
0.68150085	0.72306648	0.81463492	0.79578806	0.82835606	0.84865015	0.79933107
VIX	**Liquidity_EU**	**Liquidity_US**				
0.76885286	0.79196816	0.79296158				

Prior Communality Estimates: ONE				
Eigenvalues of the Correlation Matrix: Total = 31 Average = 1				
	Eigenvalue	**Difference**	**Proportion**	**Cumulative**
1	126.931.457	14.347.865	0.4095	0.4095
2	112.583.593	95.465.032	0.3632	0.7726
3	17.118.561	0.2808359	0.0552	0.8279
4	14.310.202	0.5118131	0.0462	0.8740
5	0.9192070	0.1343166	0.0297	0.9037
6	0.7848904	0.2733129	0.0253	0.9290
7	0.5115775	0.1087124	0.0165	0.9455
8	0.4028651	0.0890756	0.0130	0.9585
9	0.3137895	0.0999707	0.0101	0.9686
10	0.2138188	0.0485289	0.0069	0.9755
11	0.1652899	0.0288682	0.0053	0.9808
12	0.1364217	0.0117198	0.0044	0.9852
13	0.1247020	0.0546520	0.0040	0.9893
14	0.0700499	0.0129693	0.0023	0.9915
15	0.0570806	0.0172423	0.0018	0.9934
16	0.0398383	0.0074748	0.0013	0.9946
17	0.0323636	0.0023466	0.0010	0.9957
18	0.0300170	0.0046981	0.0010	0.9967
19	0.0253188	0.0046204	0.0008	0.9975
20	0.0206984	0.0081332	0.0007	0.9981
21	0.0125652	0.0010062	0.0004	0.9985
22	0.0115590	0.0011227	0.0004	0.9989
23	0.0104363	0.0035825	0.0003	0.9993
24	0.0068538	0.0015323	0.0002	0.9995
25	0.0053215	0.0016076	0.0002	0.9996
26	0.0037139	0.0009467	0.0001	0.9998
27	0.0027672	0.0008799	0.0001	0.9999
28	0.0018873	0.0003310	0.0001	0.9999
29	0.0015563	0.0006113	0.0001	10.000
30	0.0009451	0.0008605	0.0000	10.000
31	0.0000846		0.0000	10.000
5 factors will be retained by the MINEIGEN criterion.				

		Factor Pattern				
		Factor1	Factor2	Factor3	Factor4	Factor5
EURO_TWI	EURO_TWI	97	-15	-13	-3	11
EURODOLL	EURODOLL	95	-20	-20	-1	9
EUROYEN	EUROYEN	94	-27	8	13	6
EUSA_3M05	EUSA_3M05	92	-33	8	1	5
Inflation_France	Inflation_France	83	22	-2	11	20
EUSA_SLOPE	EUSA_SLOPE	80	-21	35	-22	17
EUROROUBLE	EUROROUBLE	79	-56	-9	0	-1
US_rate_slope	US_rate_slope	78	30	44	-6	-17
Eurostoxx	Eurostoxx	71	55	-8	23	-19
HSI	HSI	67	36	-33	40	11
VIX	VIX	-60	-46	-19	-17	44
Liquidity_EU	Liquidity_EU	-64	-57	23	25	-20
GOLD	GOLD	-66	59	-28	18	16
Liquidity_US	Liquidity_US	-72	-45	-19	26	17
ASIAN_TWI	ASIAN_TWI	-79	-46	29	1	-18
YEN_TWI	YEN_TWI	-81	23	-39	-29	-1
LIBOR	LIBOR	-81	-47	12	26	1
DOLLAR_TWI	DOLLAR_TWI	-94	-5	27	0	-4
SP500	SP500	-4	95	11	21	4
IBOV	IBOV	13	94	-16	11	-3
COPPER	COPPER	0	92	14	21	-15
GSCI	GSCI	10	90	21	26	-13
Taux_SWAP_inflation_FR_1an	Taux_SWAP_inflation_FR_1an	-38	87	-9	-8	13
Inflation_US	Inflation_US	8	84	20	14	15
SLOPE_FORWARD_EUSA	SLOPE_FORWARD_EUSA	-45	71	31	-17	4
swap_rate_curve	swap_rate_curve	46	-80	8	4	-5
SPREAD_EU_CMPNY	SPREAD_EU_CMPNY	-48	-83	-1	13	-3
SPREAD_US_CMPNY	SPREAD_US_CMPNY	42	-89	3	6	0
EURIBOR	EURIBOR	5	-94	8	24	-11
Var_Oil_RSV	Var_Oil_RSV	7	28	49	-44	30
SPREAD_WTIBRENT	SPREAD_WTIBRENT	30	24	-41	-55	-49
	Printed values are multiplied by 100 and rounded to the nearest integer.					

Variance Explained by Each Factor				
Factor1	Factor2	Factor3	Factor4	Factor5
12.693.146	11.258.359	1.711.856	1.431.020	0.919207

		Rotated Factor pattern			
		Factor1	Factor2	Factor3	Factor4	Factor5
SP500	SP500	95	11	-19	1	-8
Taux_SWAP_inflation_FR_1an	Taux_SWAP_inflation_FR_1an	92	-15	19	7	11
IBOV	IBOV	90	31	-12	-10	16
COPPER	COPPER	89	8	-34	-4	1
GSCI	GSCI	86	16	-41	-1	-6
Inflation_US	Inflation_US	82	20	-18	17	-14
SLOPE_FORWARD_EUSA	SLOPE_FORWARD_EUSA	76	-38	-4	33	3
GOLD	GOLD	75	-37	39	-26	-7
SPREAD_EU_CMPNY	SPREAD_EU_CMPNY	-68	-56	22	-22	-23
EUROROUBLE	EUROROUBLE	-71	65	-17	-2	3
swap_rate_curve	swap_rate_curve	-87	25	-16	-1	-11
EURIBOR	EURIBOR	-90	-14	-8	-22	-27
SPREAD_US_CMPNY	SPREAD_US_CMPNY	-94	24	-7	-4	-15
EURO_TWI	EURO_TWI	-34	91	-16	7	8
EURODOLL	EURODOLL	-38	90	-13	0	9
Inflation_France	Inflation_France	7	85	-20	10	-7
HSI	HSI	26	81	-11	-32	-9
EUROYEN	EUROYEN	-44	81	-34	7	-11
EUSA_3M05	EUSA_3M05	-51	77	-30	14	-4
Eurostoxx	Eurostoxx	39	71	-45	-15	12
EUSA_SLOPE	EUSA_SLOPE	-38	62	-30	51	-4
Liquidity_US	Liquidity_US	-23	-60	47	-34	-33
YEN_TWI	YEN_TWI	37	-61	55	-13	34
Liquidity_EU	Liquidity_EU	-41	-77	-3	-21	-30
LIBOR	LIBOR	-25	-81	21	-21	-37
ASIAN_TWI	ASIAN_TWI	-30	-91	4	-2	-17
DOLLAR_TWI	DOLLAR_TWI	14	-94	15	5	-18
VIX	VIX	-29	-44	72	6	-16
US_rate_slope	US_rate_slope	9	58	-67	36	6
Var_Oil_RSV	Var_Oil_RSV	22	3	-4	74	-2
SPREAD_WTIBRENT	SPREAD_WTIBRENT	7	24	-8	-4	89
	Printed values are multiplied by 100 and rounded to the nearest integer.					

Variance Explained by Each Factor				
Factor1	Factor2	Factor3	Factor4	Factor5
11.110.971	10.791.604	2.833.864	1.660.003	1.617.147

Appendix n°009: PCA of the High correlation period n°2

The complete SAS outputs are available on the attached CD.

PCA RESULT	
data set from PROC SCORE	
The FACTOR Procedure	
Input Data Type	Raw Data
Number of Records Read	48
Number of Records Used	48
N for Significance Tests	48

Kaiser's Measure of Sampling Adequacy: Overall MSA = 0.70578212						
Inflation_France	**Inflation_US**	**Taux_SWAP_inflation_FR_1an**	**swap_rate_curve**	**EURIBOR**	**LIBOR**	**EUSA_3M05**
0.59741097	0.63543490	0.77725119	0.58985155	0.86758225	0.85191888	0.67928535
SLOPE_FORWARD_EUSA	**SPREAD_EU_CMPNY**	**SPREAD_US_CMPNY**	**EUSA_SLOPE**	**US_rate_slope**	**EURODOLL**	**EUROYEN**
0.61362382	0.85402420	0.79663243	0.65887527	0.79795595	0.62744211	0.61121639
EUROROUBLE	**ASIAN_TWI**	**EURO_TWI**	**DOLLAR_TWI**	**YEN_TWI**	**SPREAD_WTIBRENT**	**Var_Oil_RSV**
0.66989396	0.77212307	0.80770193	0.70453951	0.54156460	0.66932945	0.32622295
SP500	**Eurostoxx**	**HSI**	**IBOV**	**GSCI**	**GOLD**	**COPPER**
0.77184268	0.85731795	0.66851832	0.81719063	0.57309747	0.72163256	0.62731069
VIX	**Liquidity_EU**	**Liquidity_US**				
0.84485274	0.73095729	0.85510330				

Prior Communality Estimates: ONE				
Eigenvalues of the Correlation Matrix: Total = 31 Average = 1				
	Eigenvalue	**Difference**	**Proportion**	**Cumulative**
1	126.603.421	21.406.141	0.4084	0.4084
2	105.197.280	81.391.713	0.3393	0.7477
3	23.805.567	0.7687840	0.0768	0.8245
4	16.117.727	0.5075740	0.0520	0.8765
5	11.041.986	0.3209942	0.0356	0.9121
6	0.7832044	0.3330770	0.0253	0.9374
7	0.4501274	0.1303665	0.0145	0.9519
8	0.3197608	0.0145318	0.0103	0.9622
9	0.3052291	0.1287734	0.0098	0.9721
10	0.1764556	0.0370032	0.0057	0.9778
11	0.1394525	0.0318846	0.0045	0.9823
12	0.1075679	0.0074751	0.0035	0.9858
13	0.1000928	0.0282673	0.0032	0.9890
14	0.0718255	0.0049988	0.0023	0.9913
15	0.0668267	0.0175850	0.0022	0.9935
16	0.0492417	0.0072793	0.0016	0.9950
17	0.0419623	0.0171660	0.0014	0.9964
18	0.0247963	0.0031680	0.0008	0.9972
19	0.0216283	0.0070400	0.0007	0.9979
20	0.0145883	0.0001714	0.0005	0.9984
21	0.0144169	0.0006215	0.0005	0.9988
22	0.0137954	0.0072031	0.0004	0.9993
23	0.0065923	0.0021103	0.0002	0.9995
24	0.0044820	0.0012094	0.0001	0.9996
25	0.0032726	0.0006415	0.0001	0.9997
26	0.0026310	0.0005806	0.0001	0.9998
27	0.0020505	0.0005405	0.0001	0.9999
28	0.0015100	0.0003917	0.0000	0.9999
29	0.0011183	0.0005114	0.0000	10.000
30	0.0006069	0.0004403	0.0000	10.000
31	0.0001666		0.0000	10.000
5 factors will be retained by the MINEIGEN criterion.				

	Factor Pattern					
		Factor1	Factor2	Factor3	Factor4	Factor5
Inflation_US	**Inflation_US**	92	-16	-12	13	-3
HSI	**HSI**	92	-4	-13	-17	16
Eurostoxx	**Eurostoxx**	87	9	31	-12	-4
COPPER	**COPPER**	85	37	-8	-13	27
Inflation_France	**Inflation_France**	79	13	41	-21	-1
SP500	**SP500**	78	-58	4	-11	-9
IBOV	**IBOV**	78	47	-14	-29	7
SLOPE_FORWARD_EUSA	**SLOPE_FORWARD_EUSA**	76	-14	53	-9	-8
GOLD	**GOLD**	72	21	37	40	26
GSCI	**GSCI**	71	55	-3	-7	36
EUROYEN	**EUROYEN**	60	54	-51	14	-19
Var_Oil_RSV	**Var_Oil_RSV**	37	28	-36	25	19
EUROROUBLE	**EUROROUBLE**	-64	7	38	56	-2
VIX	**VIX**	-67	47	-9	44	12
SPREAD_US_CMPNY	**SPREAD_US_CMPNY**	-69	69	10	-13	8
SPREAD_WTIBRENT	**SPREAD_WTIBRENT**	-73	54	13	5	-5
DOLLAR_TWI	**DOLLAR_TWI**	-73	-53	-20	-27	-13
SPREAD_EU_CMPNY	**SPREAD_EU_CMPNY**	-78	59	2	-9	8
EUSA_3M05	**EUSA_3M05**	-21	94	-16	1	-13
EURIBOR	**EURIBOR**	-39	91	-2	-7	7
Liquidity_EU	**Liquidity_EU**	-46	87	9	-9	2
EURO_TWI	**EURO_TWI**	33	86	-23	28	0
Taux_SWAP_inflation_FR_1an	**Taux_SWAP_inflation_FR_1an**	32	81	30	-5	2
US_rate_slope	**US_rate_slope**	32	81	-25	-18	-32
Liquidity_US	**Liquidity_US**	-56	78	8	-24	0
EURODOLL	**EURODOLL**	51	78	-10	31	4
LIBOR	**LIBOR**	-53	75	1	-35	8
ASIAN_TWI	**ASIAN_TWI**	-54	-68	-26	0	-13
swap_rate_curve	**swap_rate_curve**	-9	-69	-47	18	32
YEN_TWI	**YEN_TWI**	-63	-29	64	-1	28
EUSA_SLOPE	**EUSA_SLOPE**	53	34	29	31	-58
	Printed values are multiplied by 100 and rounded to the nearest integer.					

Variance Explained by Each Factor				
Factor1	**Factor2**	**Factor3**	**Factor4**	**Factor5**
12.660.342	10.519.728	2.380.557	1.611.773	1.104.199

		Rotated Factor pattern				
		Factor1	Factor2	Factor3	Factor4	Factor5
Liquidity_US	Liquidity_US	99	-1	-1	-2	7
SPREAD_US_CMPNY	SPREAD_US_CMPNY	98	-8	-9	13	-3
LIBOR	LIBOR	98	-2	0	-15	-4
Liquidity_EU	Liquidity_EU	97	11	11	8	8
EURIBOR	EURIBOR	95	13	23	6	2
SPREAD_EU_CMPNY	SPREAD_EU_CMPNY	93	-22	-10	18	-8
EUSA_3M05	EUSA_3M05	84	11	47	4	18
SPREAD_WTIBRENT	SPREAD_WTIBRENT	83	-19	-12	30	8
VIX	VIX	66	-21	12	61	-14
Inflation_US	Inflation_US	-69	45	43	-20	10
SP500	SP500	-88	24	1	-35	11
GOLD	GOLD	-30	86	20	24	5
GSCI	GSCI	6	78	48	-27	-15
Inflation_France	Inflation_France	-28	75	1	-36	28
COPPER	COPPER	-15	73	49	-38	-10
Eurostoxx	Eurostoxx	-38	72	13	-33	28
Taux_SWAP_inflation_FR_1an	Taux_SWAP_inflation_FR_1an	48	69	26	-9	27
SLOPE_FORWARD_EUSA	SLOPE_FORWARD_EUSA	-50	67	-17	-22	34
IBOV	IBOV	-2	61	52	-54	6
HSI	HSI	-52	54	37	-46	-7
ASIAN_TWI	ASIAN_TWI	-25	-81	-31	10	-16
DOLLAR_TWI	DOLLAR_TWI	4	-84	-45	-7	-16
EUROYEN	EUROYEN	1	25	92	-18	17
EURO_TWI	EURO_TWI	41	44	77	11	11
EURODOLL	EURODOLL	24	61	71	11	15
US_rate_slope	US_rate_slope	45	26	65	-34	37
Var_Oil_RSV	Var_Oil_RSV	-6	23	58	5	-19
YEN_TWI	YEN_TWI	19	-5	-88	35	-16
EUROROUBLE	EUROROUBLE	32	-14	-32	80	10
EUSA_SLOPE	EUSA_SLOPE	-12	42	32	14	78
swap_rate_curve	swap_rate_curve	-54	-46	1	12	-57
	Printed values are multiplied by 100 and rounded to the nearest integer.					

Variance Explained by Each Factor				
Factor1	Factor2	Factor3	Factor4	Factor5
10.721.669	7.499.213	5.541.411	2.760.805	1.753.500

Appendix n°010: Linear regression on low correlation n°1

The complete SAS outputs are available on the attached CD.

Backward elimination step 0

All Variables Entered: R-Square = 0.7958 and C(p) = 7.0000

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	1795.31262	299.21877	26.64	<.0001
Error	41	460.55608	11.23308		
Corrected Total	47	2255.86870			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	64.91979	0.48376	202300	18009.3	<.0001
FT1	5.79930	0.48888	1580.70095	140.72	<.0001
FT2	0.76329	0.48888	27.38308	2.44	0.1261
FT3	1.56082	0.48888	114.49922	10.19	0.0027
FT4	-0.59270	0.48888	16.51057	1.47	0.2323
FT5	-0.27603	0.48888	3.58100	0.32	0.5754
FT6	-1.05828	0.48888	52.63780	4.69	0.0363

Backward elimination: last step

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1747.83797	582.61266	50.46	<.0001
Error	44	508.03073	11.54615		
Corrected Total	47	2255.86870			

Root MSE	3.39796	R-Square	0.7748
Dependent Mean	64.91979	Adj R-Sq	0.7594
Coeff Var	5.23409		

Parameter Estimates									
Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate	Tolerance	Variance Inflation
Intercept	Intercept	1	64.91979	0.49045	132.37	<.0001	0	.	0
FT1	FT1	1	5.79930	0.49564	11.70	<.0001	0.83708	1.00000	1.00000
FT3	FT3	1	1.56082	0.49564	3.15	0.0029	0.22529	1.00000	1.00000
FT6	FT6	1	-1.05828	0.49564	-2.14	0.0384	-0.15275	1.00000	1.00000

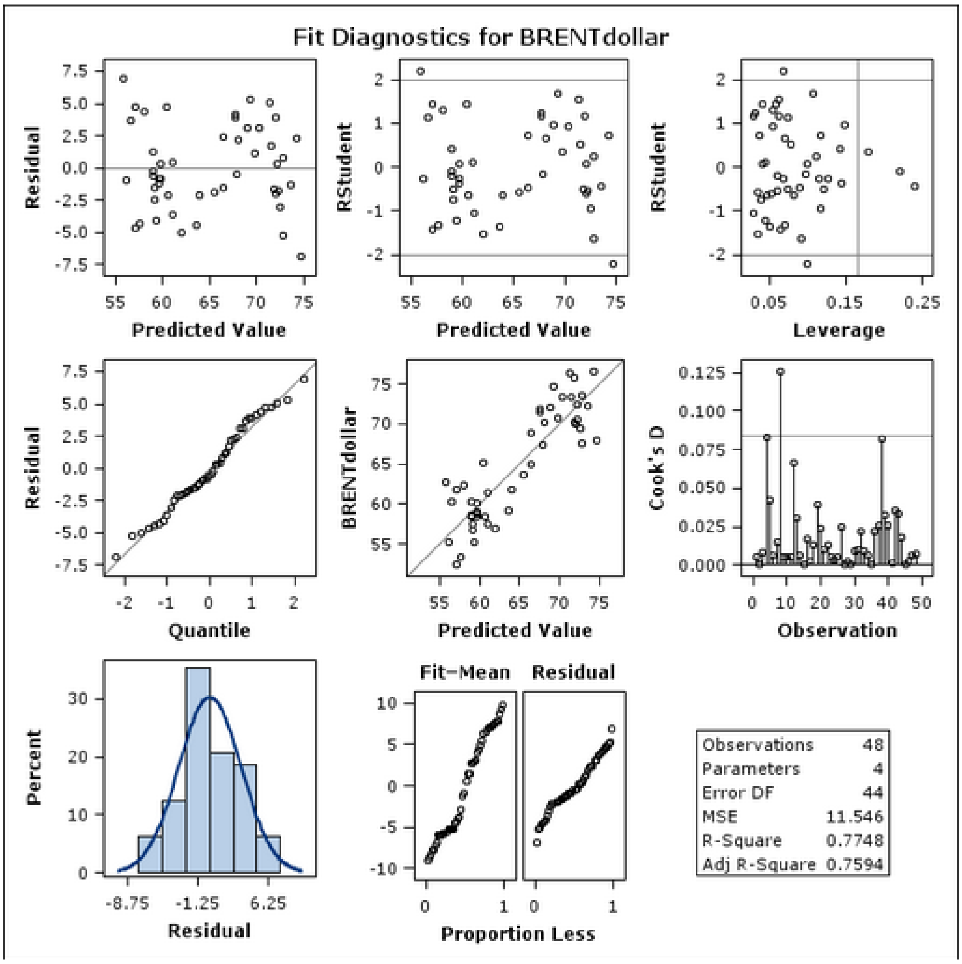
Regression linéaire

The REG Procedure
Model: MODEL1
Dependent Variable: BRENTdollar BRENTdollar

Test of First and Second Moment Specification		
DF	Chi-Square	Pr > ChiSq
9	11.69	0.2316

Durbin-Watson D	0.608
Number of Observations	48
1st Order Autocorrelation	0.692

The REG Procedure
Model: MODEL1
Dependent Variable: BRENTdollar BRENTdollar



Appendix n°011: Linear regression on High correlation n°1

The complete SAS outputs are available on the attached CD.

Backward elimination first and last step

Regression linéaire

The REG Procedure
Model: MODEL1
Dependent Variable: BRENTdollar BRENTdollar

Number of Observations Read	77
Number of Observations Used	77

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	38925	6487.43240	502.19	<.0001
Error	70	904.28673	12.91838		
Corrected Total	76	39829			

Root MSE	3.59422	**R-Square**	0.9773
Dependent Mean	92.54896	**Adj R-Sq**	0.9753
Coeff Var	3.88358		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate	Tolerance	Variance Inflation
Intercept	Intercept	1	92.54896	0.40960	225.95	<.0001	0	.	0
FT1	FT1	1	20.24054	0.41228	49.09	<.0001	0.88416	1.00000	1.00000
FT2	FT2	1	6.21319	0.41228	15.07	<.0001	0.27141	1.00000	1.00000
FT3	FT3	1	7.65371	0.41228	18.56	<.0001	0.33433	1.00000	1.00000
FT4	FT4	1	0.93590	0.41228	2.27	0.0263	0.04088	1.00000	1.00000
FT5	FT5	1	-1.00883	0.41228	-2.45	0.0169	-0.04407	1.00000	1.00000
FT6	FT6	1	-1.84651	0.41228	-4.48	<.0001	-0.08066	1.00000	1.00000

Regression linéaire

The REG Procedure
Model: MODEL1
Dependent Variable: BRENTdollar BRENTdollar

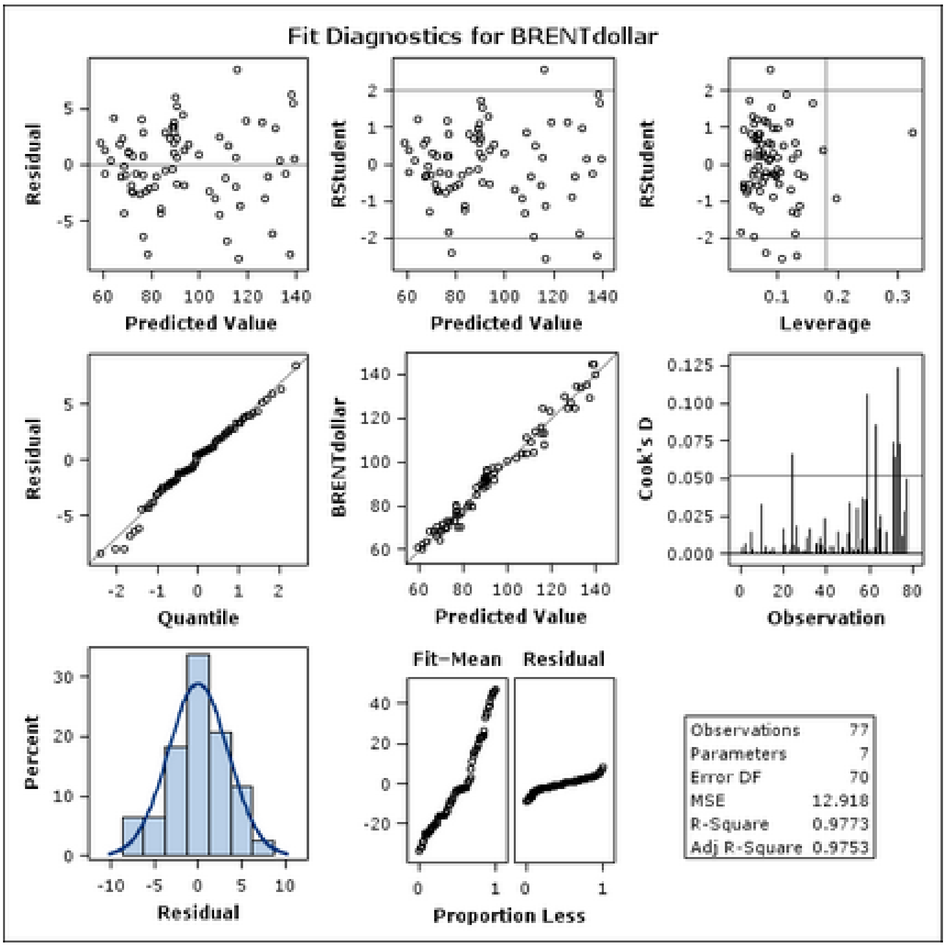
Test of First and Second Moment Specification

DF	Chi-Square	Pr > ChiSq
27	19.50	0.8512

Durbin-Watson D	0.962
Number of Observations	77
1st Order Autocorrelation	0.515

Regression linéaire

The REG Procedure
Model: MODEL1
Dependent Variable: BRENTdollar BRENTdollar



Appendix n°012: Linear regression on low correlation n°2

The complete SAS outputs are available on the attached CD.

Backward elimination step 0

All Variables Entered: R-Square = 0.7660 and C(p) = 6.0000

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	5	918.89659	183.77932	29.46	<.0001
Error	45	280.73856	6.23863		
Corrected Total	50	1199.63514			

Variable	**Parameter Estimate**	**Standard Error**	**Type II SS**	**F Value**	**Pr > F**
Intercept	75.25176	0.34975	288804	46292.9	<.0001
FT1	3.80267	0.35323	723.01398	115.89	<.0001
FT2	0.35024	0.35323	6.13339	0.98	0.3267
FT3	-1.41892	0.35323	100.66602	16.14	0.0002
FT4	-0.38719	0.35323	7.49568	1.20	0.2789
FT5	-1.27740	0.35323	81.58752	13.08	0.0008

Backward elimination: last step

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	3	905.26751	301.75584	48.18	<.0001
Error	47	294.36763	6.26314		
Corrected Total	50	1199.63514			

Root MSE	2.50263	**R-Square**	0.7546
Dependent Mean	75.25176	**Adj R-Sq**	0.7390
Coeff Var	3.32567		

Parameter Estimates									
Variable	**Label**	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**	**Standardized Estimate**	**Tolerance**	**Variance Inflation**
Intercept	Intercept	1	75.25176	0.35044	214.74	<.0001	0	.	0
FT1	FT1	1	3.80267	0.35392	10.74	<.0001	0.77633	1.00000	1.00000
FT3	FT3	1	-1.41892	0.35392	-4.01	0.0002	-0.28968	1.00000	1.00000
FT5	FT5	1	-1.27740	0.35392	-3.61	0.0007	-0.26079	1.00000	1.00000

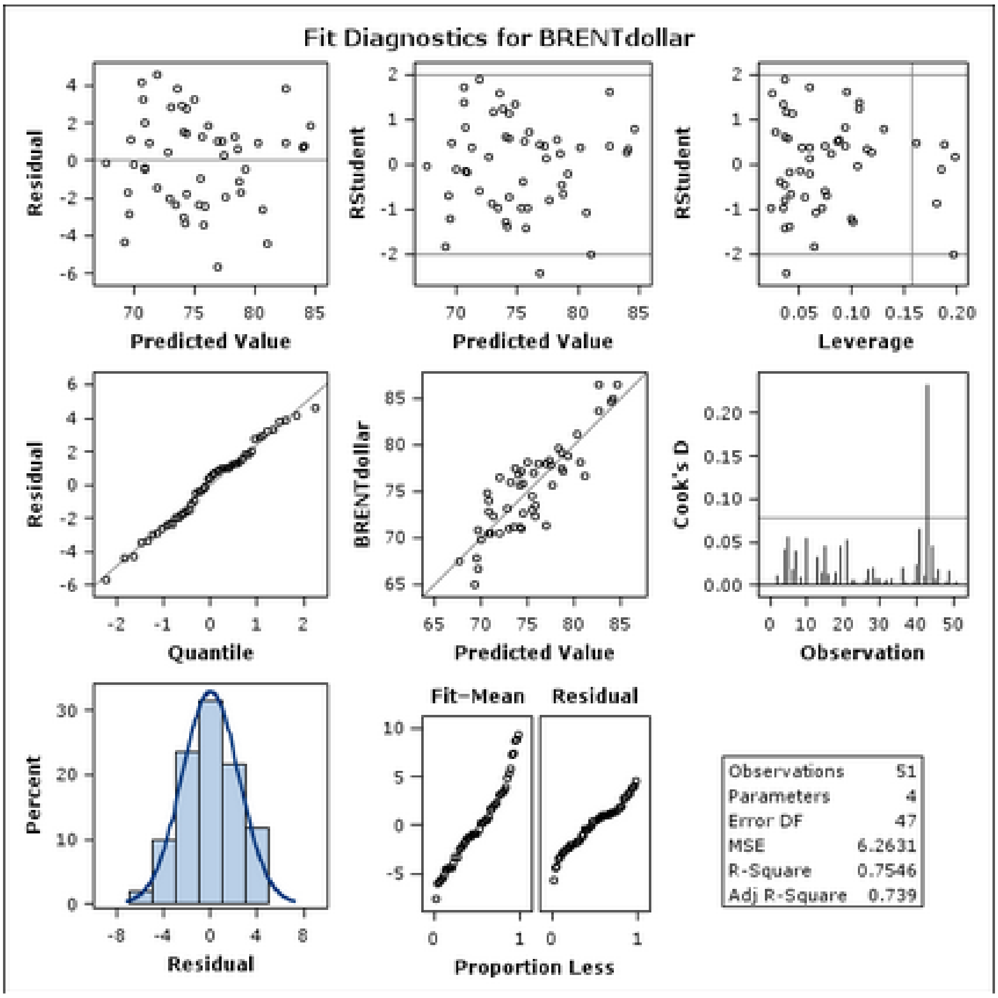
The REG Procedure
Model: MODEL1
Dependent Variable: BRENTdollar BRENTdollar

Test of First and Second Moment Specification		
DF	**Chi-Square**	**Pr > ChiSq**
9	14.25	0.1136

Durbin-Watson D	0.974
Number of Observations	51
1st Order Autocorrelation	0.509

Regression linéaire

The REG Procedure
Model: MODEL1
Dependent Variable: BRENTdollar BRENTdollar



Appendix n°013: Linear regression on High correlation n°2

The complete SAS outputs are available on the attached CD.

Linear regression without backward elimination

The REG Procedure
Model: MODEL1
Dependent Variable: BRENTdollar BRENTdollar

Number of Observations Read	48
Number of Observations Used	48

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	2718.74090	543.74818	30.24	<.0001
Error	42	755.18025	17.98048		
Corrected Total	47	3473.92115			

Root MSE	4.24034	R-Square	0.7826
Dependent Mean	112.93729	Adj R-Sq	0.7567
Coeff Var	3.75460		

Parameter Estimates									
Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate	Tolerance	Variance Inflation
Intercept	Intercept	1	112.93729	0.61204	184.53	<.0001	0	.	0
FT1	FT1	1	-1.02799	0.61852	-1.66	0.1040	-0.11957	1.00000	1.00000
FT2	FT2	1	4.36309	0.61852	7.05	<.0001	0.50750	1.00000	1.00000
FT3	FT3	1	4.10065	0.61852	6.63	<.0001	0.47697	1.00000	1.00000
FT4	FT4	1	-4.35544	0.61852	-7.04	<.0001	-0.50661	1.00000	1.00000
FT5	FT5	1	1.40254	0.61852	2.27	0.0286	0.16314	1.00000	1.00000

Regression linéaire

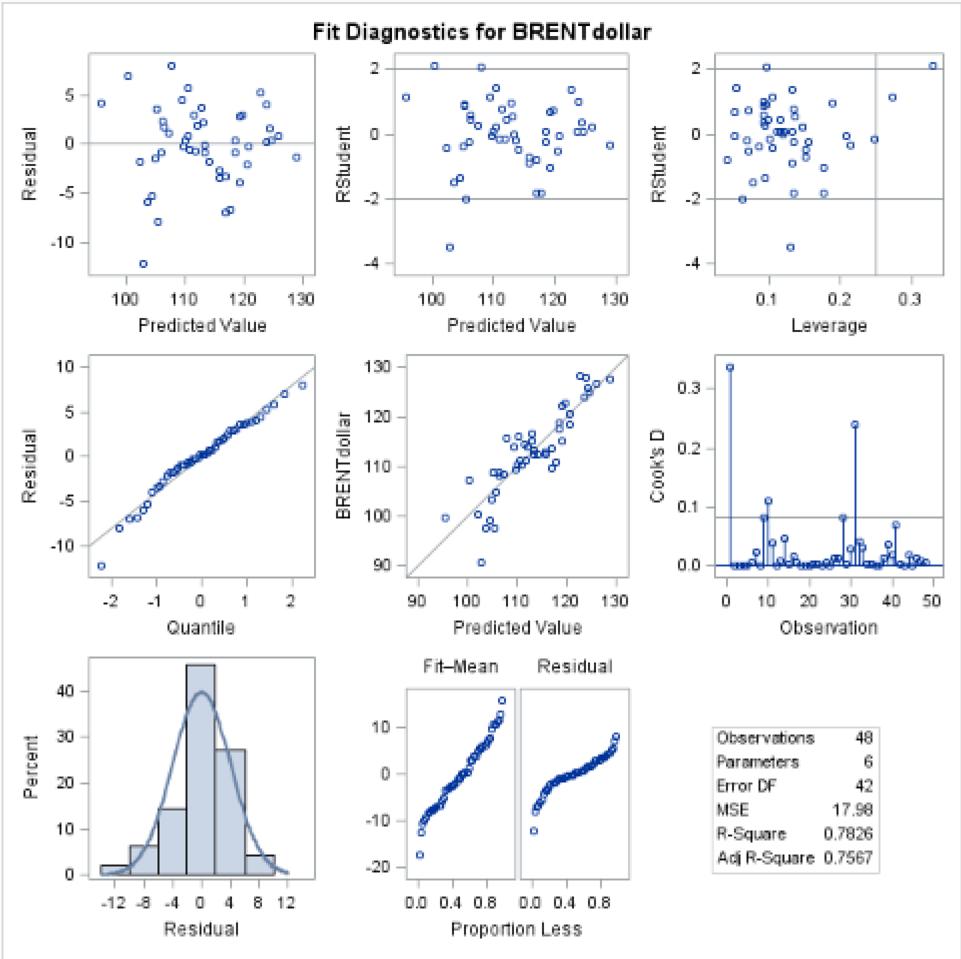
The REG Procedure
Model: MODEL1
Dependent Variable: BRENTdollar BRENTdollar

Test of First and Second Moment Specification		
DF	Chi-Square	Pr > ChiSq
20	18.27	0.5696

Durbin-Watson D	0.773
Number of Observations	48
1st Order Autocorrelation	0.578

Regression linéaire

The REG Procedure
Model: MODEL1
Dependent Variable: BRENTdollar BRENTdollar



Appendix n°014 : GARCH code

Source : SAS support, http://support.sas.com/rnd/app/examples/ets/garchex/, website, accessed the 13/07/2013

```
 /* Estimate GARCH(1,1) with normally distributed residuals with MODEL*/
proc model data = normal ;
    parms arch0 .1 arch1 .2 garch1 .75 ;
    /* mean model */
    y = intercept ;
    /* variance model */
    h.y = arch0 + arch1*xlag(resid.y**2,mse.y) +
          garch1*xlag(h.y,mse.y) ;
    /* fit the model */
    fit y / method = marquardt fiml ;
run ;
quit ;
```

Appendix n°015: Conditional variance Brent Dollar (Spot)

The complete SAS outputs are available on the attached CD.

The SAS System

The MODEL Procedure

Nonlinear FIML Summary of Residual Errors								
Equation	DF Model	DF Error	SSE	MSE	Root MSE	R-Square	Adj R-Sq	Label
Var_R_Brentdollar	3	25	3.476E-6	1.39E-7	0.000373	0.4996	0.4596	Var_R_Brentdollar

Nonlinear FIML Parameter Estimates				
Parameter	Estimate	Approx Std Err	t Value	Approx Pr > |t|
intercept	0.000162	0.000118	1.37	0.1819
ARCH1	0.002581	0.000988	2.61	0.0150
GARCH1	0.475717	0.1614	2.95	0.0068

Number of Observations		Statistics for System	
Used	28	Log Likelihood	182.8959
Missing	3		

Appendix n°016: Conditional variance CO4

The complete SAS outputs are available on the attached CD.

The SAS System

The MODEL Procedure

Nonlinear FIML Summary of Residual Errors								
Equation	DF Model	DF Error	SSE	MSE	Root MSE	R-Square	Adj R-Sq	Label
Var_R_CO4	3	25	2.769E-6	1.108E-7	0.000333	0.4076	0.3603	Var_R_CO4

Nonlinear FIML Parameter Estimates				
Parameter	Estimate	Approx Std Err	t Value	Approx Pr > |t|
intercept	0.000151	0.000151	1.00	0.3258
ARCH1	0.000986	0.00229	0.43	0.6701
GARCH1	0.547289	0.3351	1.63	0.1150

Number of Observations		Statistics for System	
Used	28	Log Likelihood	186.0784
Missing	3		

Appendix n°017: Conditional variance CO24

The complete SAS outputs are available on the attached CD.

The SAS System

The MODEL Procedure

Nonlinear FIML Summary of Residual Errors								
Equation	DF Model	DF Error	SSE	MSE	Root MSE	R-Square	Adj R-Sq	Label
Var_R_CO24	3	25	8.574E-7	3.429E-8	0.000185	0.3140	0.2591	Var_R_CO24

Nonlinear FIML Parameter Estimates				
Parameter	Estimate	Approx Std Err	t Value	Approx Pr > |t|
intercept	0.000103	0.000124	0.83	0.4141
ARCH1	-0.0004	0.00224	-0.18	0.8584
GARCH1	0.605101	0.3656	1.66	0.1104

Number of Observations		Statistics for System	
Used	28	Log Likelihood	202.4923
Missing	3		

Appendix n°018: Conditional covariance spot-CO4

The complete SAS outputs are available on the attached CD.

The SAS System

The MODEL Procedure

Nonlinear FIML Summary of Residual Errors								
Equation	DF Model	DF Error	SSE	MSE	Root MSE	R-Square	Adj R-Sq	Label
Covar_CO4	3	25	6.91E-10	2.76E-11	5.258E-6	0.4523	0.4084	Covar_CO4

Nonlinear FIML Parameter Estimates				
Parameter	Estimate	Approx Std Err	t Value	Approx Pr > |t|
intercept	-1.17E-6	1.932E-6	-0.61	0.5501
ARCH1	0.000072	0.000011	6.82	<.0001
GARCH1	0.178635	0.1402	1.27	0.2142

Number of Observations		Statistics for System	
Used	28	Log Likelihood	302.2176
Missing	3		

Appendix n°019 Conditional covariance spot-CO24

The complete SAS outputs are available on the attached CD.

The SAS System

The MODEL Procedure

Nonlinear FIML Summary of Residual Errors								
Equation	DF Model	DF Error	SSE	MSE	Root MSE	R-Square	Adj R-Sq	Label
Covar_CO24	3	25	1.124E-6	4.497E-8	0.000212	0.3713	0.3210	Covar_CO24

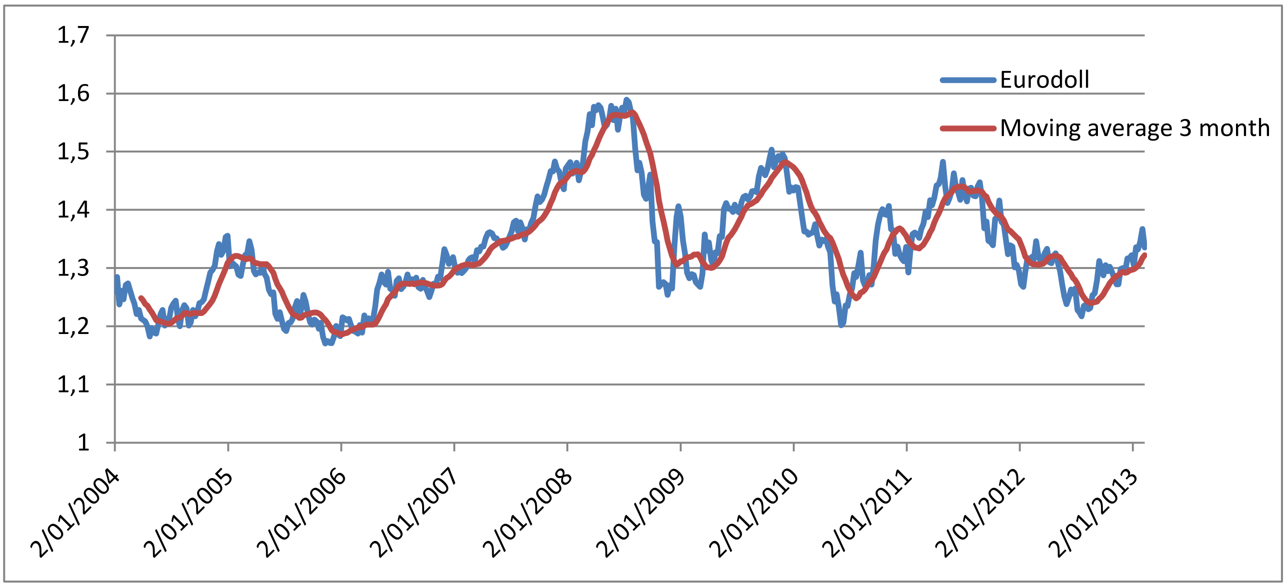
Nonlinear FIML Parameter Estimates				
Parameter	Estimate	Approx Std Err	t Value	Approx Pr > |t|
intercept	0.00011	0.000141	0.78	0.4448
ARCH1	-5.42E-6	0.00201	-0.00	0.9979
GARCH1	0.612553	0.3583	1.71	0.0997

Number of Observations		Statistics for System	
Used	28	Log Likelihood	198.6990
Missing	3		

Appendix n°020: moving average and correlation detection

Data from Bloomberg

Euro-Dollar moving average:



Correlation signal