Risk Premium in Brent Crude and TTF European Gas

Derivatives and Risk Management

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Abstract

This study explores the presence of risk premium in Brent Crude and TTF European Gas. Risk premium theory is a controversial theory which explains the future prices and risk premium itself is important to study in terms of compensation for the risk transferred from hedgers to speculators and the forecasting of spot prices. To find out whether risk premium is present in future contracts of Brent crude and TTF European gas, this study uses past 20 years (2003 to 2023) of spot price and 1-month, 3-month, 6-month future price data of Brent crude. Additionally, the study takes past 18 years (2005 to 2023) of spot price and 1-month, 2-month future price data of TTF European gas. Linear regression modelling is used to explore the relationship of the basis with spot price change and the risk premium. The results of the regression shows the strong evidence of presence of risk premium in all future contracts for both Brent crude and TTF European gas. In addition, the results also explain that the basis has forecast power over the spot price of Brent crude.

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Chapter 1

Introduction and motivation

Commodities have been traded for years and are one of the most invested-in asset classes. Unlike stocks, commodities are traded for two reasons. Either the investor wants to gain some financial return, or they want to take the physical ownership of the asset for their personal or commercial use. Unlike other asset classes, commodities have distinctive features, each with own production and processing activities, and this asset class is less explored. Price of commodities is highly affected by supply and demand constraints not only on the spot but in the future as well. Out of all commodities, energy commodities, more specifically, crude oil is the top and natural gas is the third most traded commodity in the world and they are largely affected by supply, demand, political environment, policies, global human events, and natural events.

Crude oil and natural gas or commodities in general were traded by hedgers who wanted a physical delivery of the asset but wanted to hedge the price risk but soon they also become popular alternative asset class due to their low correlation with other asset classes. This popularity as investment class was further enhanced by various stock and bond market crash events such as the financial crisis of 2008 or the dotcom bubble between 1998 and 2000. This increasing attraction and popularity further led to development of commodity markets and trading. Commodity futures became popular and became the main source of hedging against price risk for the hedgers and a means to buy something in the future for reasons like future demand, storage constraints, etc., and it became a source of profit for speculators.

Due to separate trades in spot and futures market of commodities, there came the difference between the spot and future prices. Ideally, the spot price in the future and the price of a future contract both with the same maturity should be equal. However, that is not the case in real and many perspectives came into sight about the spot – future price difference of commodities. Theory of storage is one of the most undoubted, accepted, and least debated theory to explain the difference based on the time value concepts, cost of storage and return on physical holding of the asset. On the other hand, a more doubted, debated, and controversial theory to explain the difference between spot and future prices is the risk premium theory which explains the difference as the compensation for taking on the risk on behalf of the other. There have been many studies on this theory but the results of almost all studies are contradicting as some studies find the presence of risk premium while the others deny it.

The year 2023 could not have been better to study the risk premium theory as the world has recently gone through various economic shocks such as Covid-19 almost recession, and post Covid-19 rapid uncontrollable recovery, the Russian war in Ukraine, various policy changes in such a short time span, and many more which has led to serious fluctuations in the commodity markets. Additionally, considering these events, and the recent energy crisis globally, especially in Europe, it is interesting to do an analysis on Crude oil and Natural gas commodities more specifically “Brent Crude” the most traded commodity in the world, and “TTF European Gas” the benchmark natural gas price for Europe.

In order to study the risk premium theory, this study tries to answer these questions: **"Is there risk premium present in future prices of Brent Crude and TTF European Gas? and can the future prices forecast the spot prices?".** To answer these questions, this study explores the relationship between spot and future prices of Brent Crude 1-month, 3-month, and 6-month contracts along with 1-month, and 2-month future contracts of TTF European Gas using linear regression. The results of the regression analysis have concluded that there is strong evidence for the presence of risk premium in both Brent Crude and TTF European Gas whereas only the future prices of Brent crude have the forecast power over spot prices unlike TTF European gas which has no strong evidence in this regard.

Chapter 2 of this study explores the concepts of spot price, future price, and risk premium. It also discusses the importance of risk premium, drivers of risk premium, and any evidence of risk premium from previous similar studies. Chapter 3 discusses the data used for the analysis, descriptive statistics of the data, the scientific methodology used for the analysis, and some trends and events. Chapter 4 explains the results of the study along with the discussion on the flaws of this study and any future suggestions on a similar analysis. Finally, chapter 6 concludes the study.

Chapter 2

Literature Review

2.1 Spot prices, Future prices, and Risk premium.

Commodities trading especially the energy commodities such as oil, natural gas, and more, have been in the market for years and people have been trading commodities for both the financial and commercial reasons. The traders have a choice to either buy the oil at the spot or sometime in the future, each decision motivated by a specific reason. Buying spot means that the trader buys the oil at the current market price and has to take delivery of the commodity where buying future means that the trader buys the oil at a specific rate in the future which could be from months or years and take the delivery of the commodity at the expiration of the future contract. According to Alquist, R., & Kilian, L. (2010), the choice to buy spot or future of the commodity is motivated by the speculation of the price in the future.

Alquist, R., & Kilian, L. (2010) explains the difference between future and spot contracts by describing former as the contracts with lower transactions and ease of shorting, quick response to new information, immediate implementation with little up-front cash, and a flexibility defer the physical delivery or cancel the delivery by selling the contract further, and ease of offsetting. Alquist, R., & Kilian, L. (2010) also explains that the future contract gives the flexibility to the traders who would like the delivery of the physical asset in the future but have storage constraints as compared to the latter (spot) which requires spot delivery of the physical asset in addition to the greater initial cash outlay and a longer time for implementation.

The price for the future contracts is different than spot contracts prices. There are two main theories that explains this difference. Theory of storage explains that the interest forgone in terms of storing the commodity, cost of warehousing, and a convenience yield describes the difference between spot and future prices (Kaldor, 1939). On the other hand, the other theory views the future price as a split between expected future spot prices and an expected risk premium (Hazuka, 1984) which also helps future prices to explain changes in the spot prices.

The latter theory involving risk premium is controversial as compared to the theory of storage as according to Fama, E. F., & French, K. R. (2016) the presence of risk premium in future prices or the prices having the forecast power over spot prices attracts little agreement. Thus, we aim to explore whether this is actually true, or the risk premium is actually present and the future prices can forecast the spot prices. The focus of this analysis is on the crude oil and natural gas.

To better understand the view of risk premium, and the reason for the focus of this article on the risk premium theory, we should understand what the risk premium is and explore why is risk premium is important.

2.2 Why it is important? And how it is calculated?

According to Brooks, C., Prokopczuk, M., & Wu, Y. (2013), the risk premium is the addition to the spot price which compensates traders for the price risk in the future. As explained by Fama, E. F., & French, K. R. (2016) that the theory of risk premium helps in forecasting the future spot prices, it is very important for the speculators, hedgers and traders who either aim to buy or sell the physical commodity or just make a financial gain through trading of the financial contracts. Similarly, Ralph Sueppel (2021) explains the importance of risk premium theory through hedging pressure hypothesis in terms of trading that the future markets exist to transfer the risk from traders/hedgers of energy commodities to speculators who aim to earn financial returns. According to him, the speculators should earn a premium for taking on the risk by having a long position on backwarded contracts where traders/hedgers have a short position and similarly by being short on contangoed contracts where traders/hedgers have long positions.

According to the risk premium theory as mentioned by Fama, E. F., & French, K. R. (2016), the sum of expected premium and an expected change in the spot prices is same as the difference between the future price and the current spot price.

$$F(t, T) - S(t) = E_t[P(t, T)] + E_t[S(T) - S(t)] \quad (1)$$

This expected premium is then described as the difference between the future price and the future expected spot price.

$$E_t[P(t, T)] = F(t, T) - E_t[S(T)] \quad (2)$$

According to Fama, E. F., & French, K. R. (2016), the basis in the above equation is [$F(t, T) - S(t)$] and the above equation (1) and the theory of storage are alternatives. Therefore, the value of the basis could vary from being negative to zero to positive. The value of the basis will be negative when the future inventories are expected to rise, thus the future spot prices are expected to fall.

2.3 Has there been any risk premium?

Brooks et. al. (2013) has done their study on finding the presence of risk premium and changes in the spot prices of various commodities including the energy commodities. They have found that the future prices of the commodities especially crude oil and natural gas have strong power to explain the changes in the future spot prices where the presence of risk premium has some evidence, but it is not as strong as the forecast power of future prices. Fama, E. F., & French, K. R. (2016) have done a similar analysis on 21 commodities. Although they did not have energy commodities in their sample, but they have found strong evidence of forecast power of future prices in 10 out 21 commodities and evidence of the presence of expected premiums for 5 of 21 commodities.

Specific to the commodities of this study, Haff et. al. (2008) has found the forward prices predict the future spot price and the 1-month forward price as well in UK natural gas market. Additionally, they have found the presence of risk premium in forward prices of UK natural gas as opposed to US natural gas which has negative premium. Martínez, B., & Torró, H. (2018) have also explored the risk premium in UK natural gas market, and they have gathered some interesting insights regarding the premium in UK natural gas. They have focused on conventional risk premium and accrued risk premium in rolled over positions. Firstly, they have found the presence of risk premium in UK natural gas. Secondly, they have found that the conventional risk premium is significantly less than the accrued premium in roll over strategies which increases with time to delivery, more specifically from 1% to 10% between three to six months strategy horizon. They have also focused on the seasonality of the premiums and have found the risk premiums to be highly volatile and large during winter.

In addition to the natural gas market, the work done on crude oil market also produces some interesting insights. The work of Silvapulle, P., & Moosa, I. A. (1999) found that in the crude oil market, future prices have forecast power over spot prices with a bidirectional effect. Their work has found that new information is incorporated in both spot and future prices simultaneously.

Another way of explaining the risk premium theory is through hedging pressure hypothesis which states that the premium is transferred from the hedgers who produces or consumes energy to the speculators who aim to get the financial return by taking on the additional financial risk. According to Ralph Sueppel (2021) who tried to find the presence of risk premium through the study of long-short portfolio found that there is a risk premium of 7.58% a year present in the energy market. These results were in line with a similar study done by Adrian Fernandez-Perez et. al. (2021) who states that the around 8% to 12% premium can be earned by the investors if they exploit the hedgers net position on the energy commodities which is in line with the hedging pressure hypothesis.

2.4 What are the drivers of risk premium?

The difference between the spot price and the future price is explained based on the two theories mentioned above.

The theory of storage explains the difference between future price and the spot price in terms of interest forgone, storage cost and a unique component – convenience yield which can be better explained in terms of supply and demand. According to Brooks, Prokopczuk, & Wu (2013), the convenience yield is the compensation for holding the physical asset in times of crisis as the commodity could be used in the production of other products when the demand of that product is very high as compared to its supply in that time. This convenience yield is inversely related to inventory held (Brooks, Prokopczuk, & Wu, 2013).

On the other hand, Brooks, Prokopczuk, & Wu (2013) explain the difference between future price and spot price in terms of risk premium. According to them, the extent and the sign of risk premium depends on the net hedging position in the market. Therefore, it is important to understand the hedging pressure hypothesis as explained by Ralph (2021) which states that speculators are rewarded with a certain premium because they absorb the price risk that hedgers try to avoid in two positions: the hedger´s net long position (contangoed) in the futures market when speculators go short in such an expensive market, where on the other hand, speculators absorb the price risk by going long in the cheap market (backwarded) where the hedgers are net short.

Ralph (2021) also states that the net long position by the speculators is induced when the hedgers are net short (backwardation) who push the future price lower than the expected price at the time of contract maturity which leads to a negative risk premium. Similarly, the net short position of the speculators is enticed by the net long position of the hedgers (contango) who push the future prices higher than their expected value at maturity which leads to a positive risk premium.

This can also further be explained by Keynes (1930) in an article by Brooks, Prokopczuk, & Wu (2013) who combines this hedging pressure hypothesis with his theory of normal backwardation to explain the extent and the sign of risk premium. According to his theory, in a net long position of speculators, the short hedger´s high demand to mitigate their price risk leads the future price to be lower than the expected spot price which leads to a negative risk premium or vice versa.

According to Brooks, Prokopczuk, & Wu (2013), the extent and the sign of risk premium is explained by the hedging pressure theory as it depends on the net hedging position in the market.

Chapter 3

Data & Methodology

3.1 Data

The commodities used in this analysis are Brent crude oil and TTF European natural gas. For Brent crude, the data dates to last 20 years for both spot price and futures. This research focuses on the 1-month, 3-month, and 6-month future contracts of Brent crude. Additionally, for the TTF European gas, the research focuses on the last 18 years of spot price and future prices. The analysis is done on 1-month and 2-month future contracts.The data has been sourced from **"Thomson Reuters Datastream"** which is one of the most authentic and trustworthy sources of commodity prices.

Brent crude and TTF European gas are actively traded and widely recognized in the commodity/energy markets. They specifically capture the dynamics and market conditions of European energy market. Considering the recent energy policies development in Europe, sky rocketing gas and oil prices, and the shift to other energy sources resultantly because of war in Ukraine and post covid recovery, it is interesting to find out the presence of risk premium especially in times of crisis and recovery in Europe and seeing whether the future prices have power to forecast the spot prices of energy commodities in Europe which could ultimately be helpful in policy making.

Specifically, the reason for the focus on the TTF European gas is that it is not as actively traded as Henry Hub meaning that there could be small number of large players, fewer overall participants, and low volumes, trading in TTF. Thus, it is interesting to see the presence of risk premium in a smaller market. Additionally, TTF is not as much explored in terms of analysis as Henry Hub which is similar in case of Brent crude as compared to WTI. Therefore, focusing on TTF and Brent crude is the focus of this research.

	Mean	Median	Min	Max	StDev	Variance
Brent Crude Oil						
Spot price	72,14	67,83	14,92	133,32	27,39	750,04
1-month Future	72,20	67,86	24,75	134,56	26,56	705,24
3-month Future	72,23	68,26	24,59	136,29	25,93	672,22
6-month Future	72,17	67,98	24,30	138,05	25,33	641,46
TTF European Gas						
Spot price	26,47	20,13	4,59	235,55	28,61	818,79
1-month Future	27,35	20,56	4,92	235,30	29,93	895,66
2-month Future	28,18	20,89	5,34	239,75	31,00	961,18

Table 1 Descriptive Statistics.

Note: Mean shows the average of the monthly averages of spot price and futures prices of Brent Crude Oil and TTF European Gas respectively. The shows the descriptive statistics of spot prices and the 1-, 3-, and 6-month Brent Crude Futures where only 1, and 2 month TTF European Gas futures. The monthly averages of spot prices have been calculated based on the daily spot price of last 20 years from March 2003 to March 2023. For Brent Crude, the total number of observations of monthly averages are 240 where for the TTF European gas are 217.

Table 1 above show that on average the spot price of both Brent crude and TTF European Gas is lower than the future prices of all targeted maturities. Increasing average price with increasing time to maturity indicates a contangoed forward curve and a positive risk premium however the standard deviation and variance in case of Brent crude spot price is evidently higher than its subsequent futures indicating a high volatility in the spot price which could result in a negative risk premium on average as it can be seen in Table 2.

3.2 Methodology

3.2.1 Research design and approach

To test the theory of risk premium that there is risk premium present between future and spot prices and that the information about change in spot prices is present which tells the presence of forecast power, we run the regressions using the following models:

$$S(T) - S(t) = a_1 + b_1 [F(t, T) - S(t)] + u(t, T) \quad (3)$$

$$F(t, T) - S(T) = a_2 + b_2 [F(t, T) - S(t)] + z(t, T) \quad (4)$$

The basis [F(t, T) - S(t)] at *t* contains information that whether there is a presence of risk premium [F(t, T) -S(T)] or there is information about change in spot prices [S(T) -S(t)]. Positive b_1 states that there is information present in the basis about change in spot prices and thus future prices having forecast power on the spot prices where positive b_2 states that there is information present in the basis about the presence of the risk premium at *T*.

In the above regressions, the sum of slope coefficients is supposed to be 1, the sum of intercepts is expected to be 0, and the sum of each period´s residuals must be 0. This can be explained in terms of variation in the basis that the variation will be allocated somehow to the expected change in the spot price, expected premium, or a mix of both in the regression (Fama, E. F., & French, K. R., 2016).

Fama, E. F., & French, K. R. (2016) explains that while running these regressions (xx), we assume that the market forecasts of the future spot prices are rational and the spot and future prices are correct. However, the regressions (xx) allocate the basis variance due to measurement errors and irrational forecasts of spot prices. Fama, E. F., & French, K. R. (2016) explains that the in the regressions, it is easy to show that these measurement errors results in a positive value of b_1 showing the presence of forecast power where the irrational forecast of spot prices in the future prices results in a positive value of b_2 illustrating a time-varying expected premium.

	Mean	Median	Min	Max	StDev
Brent Crude Oil					
Basis 1	0,06	0,18	-12,37	11,71	2,06
Basis 3	0,09	0,07	-19,33	16,57	3,42
Basis 6	0,04	-0,03	-24,59	20,01	4,96
RP 1	-0,17	-0,70	-28,29	27,33	6,52
RP 3	-0,14	-0,92	-32,13	29,82	7,07
RP 6	-0,19	-1,30	-35,51	32,04	7,96
dS	0,23	0,98	-25,70	23,06	6,79
TTF European Gas					
Basis 1	0,89	0,12	-5,21	60,56	4,73
Basis 2	1,72	0,34	-5,86	82,39	6,73
RP 1	0,76	0,39	-63,67	126,86	13,29
RP 2	1,59	0,67	-62,60	143,04	14,58
dS	0,13	-0,20	-118,60	63,86	12,91

Table 2 Descriptive Statistics regression variables

Note: Risk premium (RP) is the difference between the monthly spot price at time *t* and the future price at time *t-1*. RP1, RP3, and RP6 in Brent Crude Oil variables indicate the risk premium for the futures with maturity of 1, 3, and 6 months respectively, where the RP1, and RP2 in TTF European Gas variables indicate the risk premium for the futures with the maturity of 1 and 2 months respectively. Basis is the difference between the monthly average spot price and future prices. Similar to risk premium, Basis1, Basis3, and Basis6 in Brent Crude variables represent the basis for futures with maturity 1, 3, and 6 months respectively where Basis1 and Basis2 in TTF European Gas variables represent the basis for futures with maturity of 1 and 2 months respectively. dS is the change in the spot price from time *t-1* to time *t*.

Table 2 above gives the descriptive statistics for the basis (explanatory variable), the risk premium (dependent variable), and the change in the spot price (dependent variable). Table 2 shows that the average risk premium for all future maturities of Brent crude is negative which indicates a higher spot price at time t than the future price at time t – 1 which is contrary to the data shown in Table 1 about average spot price and future prices. On the other hand, the risk premium for all future maturities of TTF European Gas is positive. The basis for both Brent Crude and TTF Gas is positive meaning the difference between future price at time t and the spot price at time t is positive thus indicating a contangoed forward curve.

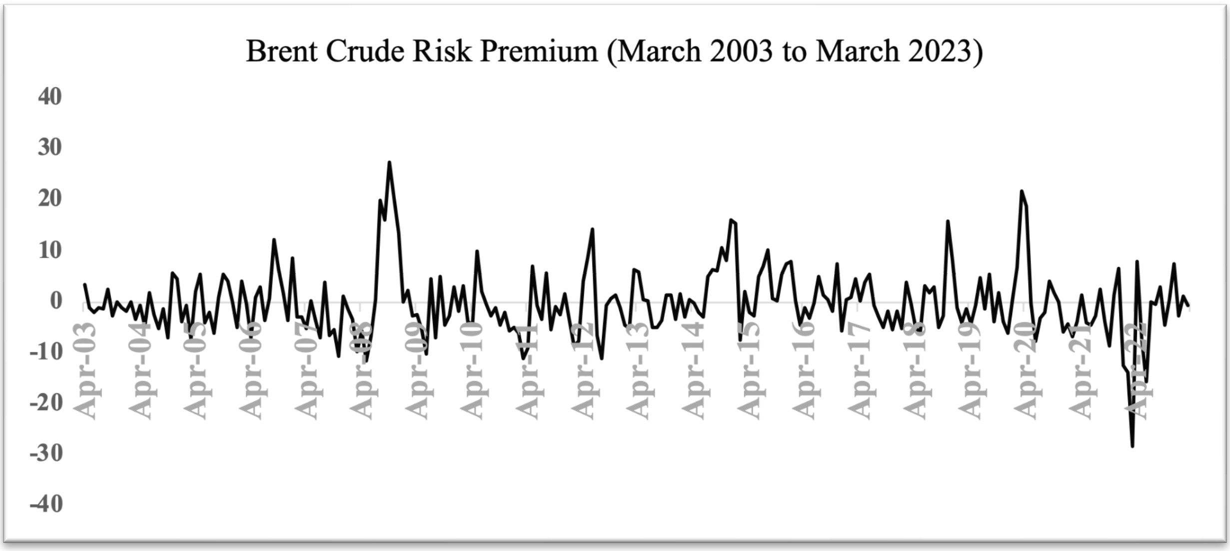

Figure 1 Brent Crude Risk Premium Trend

Note: The risk premium in USD is calculated as the difference between the monthly average spot price at time t and the monthly average future price at time t - 1. This specific risk premium represents difference between spot price and 1-month futures contract price.

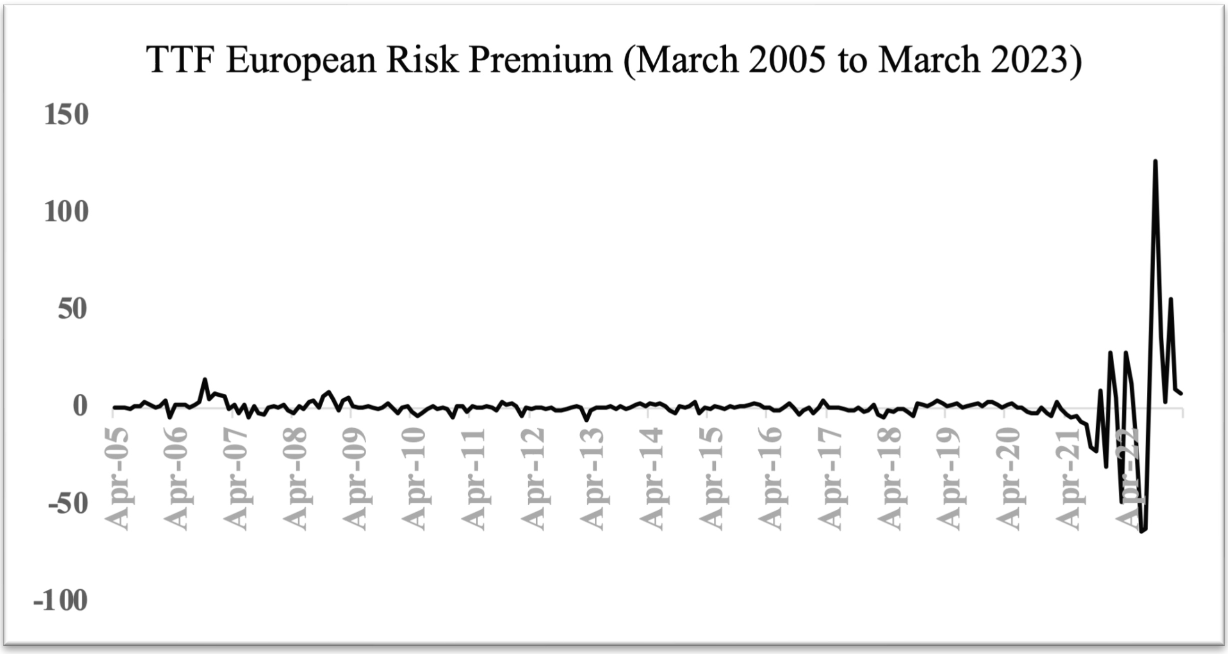

Figure 2 TTF European Gas Risk Premium Trend

Note: The risk premium in USD is calculated as the difference between the monthly average spot price at time t and the monthly average future price at time t - 1. This specific risk premium represents difference between spot price and 1-month futures contract price.

Figure 1 shows the risk premium development over the past 20 years from 2003 to 2023 for the Brent Crude Oil where the Figure 2 represents the risk premium development over the past 18 years from 2005 to 2023 for TTF European Gas. Figure 1 shows that the risk premium for Brent Crude is highly volatile and erratic and the development could be inferred as seasonal as it can be seen that the risk premium becomes positive during the summer months whereas falls to near zero or even negative in winter months. On the other hand, figure 2 shows that the risk premium development in TTF Gas appears to be stable over time with hardly any signs of seasonality or any other indications. If we look at the figures with the eye of events happened globally, two major positive fluctuations and peaks can be seen in the risk premium of Brent crude, first being the 2008 global financial crisis and second being the 2020 Covid-19 crisis where a single large negative peak can be observed in the 2022 which continued until 2023 which can be attributed to the post covid-19 economic recovery, the increased supply concerns, and the global uncertainty caused by Russian war in Ukraine. On the other hand, if we look at figure 2, the only major fluctuations in TTF European Gas are the ones in year 2022 which continued in 2023 and the reason can easily be attributed to the uncertainty due to Russian war in Ukraine, gas supply crisis in Europe because of war, and panic in the financial markets because of that.

3.2.2 Diagnostic tests

Various diagnostic tests have been run to test for autocorrelation, heteroskedasticity, and normality of the residuals:

The Durbin-Watson test for autocorrelation has revealed the presence of autocorrelation in the regression model run to study the relationship of basis with risk premium and spot price change in Brent Crude where it is absent in TTF European Gas. The Breusch-Pagan test was used to test for heteroscedasticity, and the results of the test revealed the absence of heteroscedasticity in all regression residuals except for the ones which explores the relationship of basis with risk premium and spot price change for the 2-month future contract of TTF European Gas.To test for normality of residuals, the Shapiro-Wilk test was used. The results of the tests have rejected the null hypothesis indicating the lack of normality.

Correlation analysis has also been done to see how much regression variables are correlated with each other:

Brent Crude Regression Correlation

	Basis1	Basis3	Basis6	RP1	RP3	RP6	dS
Basis1	1.000	0.956	0.894	0.019	0.189	0.315	0.284
Basis3		1.000	0.982	0.124	0.320	0.467	0.170
Basis6			1.000	0.166	0.368	0.528	0.110
RP1				1.000	0.976	0.917	′-0.953
RP3					1.000	0.980	′-0.879
RP6						1.000	′-0.784
dS							1.000

Table 3 Brent Crude Oil Regression Variables Correlation

Note: Risk premium (RP) is the difference between the monthly spot price at time *t* and the future price at time *t-1*. RP1, RP3, and RP6 variables indicate the risk premium for the futures with maturity of 1, 3, and 6 months respectively. Basis is the difference between the monthly average spot price and future prices. Similar to risk premium, Basis1, Basis3, and Basis6 variables represent the basis for futures with maturity 1, 3, and 6 months respectively. dS is the change in the spot price from time *t-1* to time *t*.

TTF European Gas Regression Correlation

	Basis1	Basis2	RP1	RP2	dS
Basis1	1.000	0.970	0.257	0.358	0.101
Basis2		1.000	0.349	0.465	´-0.004
RP1			1.000	0.989	´-0.934
RP2				1.000	´-0.886
dS					1.000

Table 4 TTF European Gas Regression Variables Correlation

Note: Risk premium (RP) is the difference between the monthly spot price at time *t* and the future price at time *t-1*. RP1, and RP2 variables indicate the risk premium for the futures with the maturity of 1 and 2 months respectively. Basis is the difference between the monthly average spot price and future prices. Similar to risk premium, Basis1 and Basis2 variables represent the basis for futures with maturity of 1 and 2 months respectively. dS is the change in the spot price from time *t-1* to time *t*.

Table 3 and 4 represent the correlation between the regression variables; Basis (explanatory variable) with RP (dependent variable), and dS (dependent variable). Table 3 shows the correlation between the regression variables of Brent Crude which appears to overall low and would not pose a serious threat to the regression modelling other than the correlation between risk premium for 6-month future and the basis. On the other hand, similar to the 6-month Brent Crude future contract, the basis correlation with dependent variables in Table 4 is between 25% to 45% and therefore considered somewhat concerning for the empirical modelling.

Chapter 4

Results

Brent Crude Spot price change and Risk premium regression results

	Obs.	a_1	a_2	b_1	b_2	$t(b_1)$	$t(b_2)$	R^2_1	R^2_2	F_1	F_2	DF_1	DF_2
1-month	240	0.172	´-0.172	0.938***	0.062	4.571	0.303	0.077	´-0.004	20.896***	0.092	238	238
3-month	240	0.197	´-0.197	0.338***	0.662***	2.665	5.214	0.025	0.099	7.103***	27.183***	238	238
6-month	240	0.222	´-0.222	0.152*	0.848***	1.721	9.615	0.002	0.277	2.961*	92.447***	238	238

Table 5 Regression on the relationship of basis with risk premium and spot price change of Brent Crude Oil

Note: a_1 represents the intercept for the relationship between spot price change and the basis where a_2 represents the intercept for the relationship between risk premium and the basis. b_1 represents the coefficient for the relationship between spot price change and the basis where b_2 represents the coefficient for the relationship between the risk premium and the basis. $t(b_1)$ and $t(b_2)$ are the t-values from the regression of the basis with spot price change and risk premium respectively. Similarly, R^2_1 and R^2_2 are the R^2 of the regression models of basis with spot price change and the risk premium respectively. Moreover, F_1, F_2, DF_1, and DF_2 shows the F-statistics of the regression models of basis with spot price change and risk premium respectively. The sum of value of coefficients of regressions for each future contract such as 1-month, 3-month, or 6-month must add up to 1 where the sum of intercepts must add up to zero. The total number of price observations within each regression are 240. The level of significance is shown using asterisks as:

* $p < 0.10$

** $p < 0.05$

*** $p < 0.01$

TTF European Gas Spot price change and Risk premium regression results

	Obs.	a_1	a_2	b_1	b_2	$t(b_1)$	$t(b_2)$	R^2_1	R^2_2	F_1	F_2	DF_1	DF_2
1-month	217	´-0.111	0.111	0.277	0.723***	1.50	3.911	0.006	0.062	2.249	15.296***	215	215
2-month	217	0.144	´-0.144	´-0.008	1.008***	´-0.06	7.713	´-0.005	0.213	0.004	59.496***	215	215

Table 6 Regression on the relationship of basis with risk premium and spot price change of TTF European Gas

Note: a_1 represents the intercept for the relationship between spot price change and the basis where a_2 represents the intercept for the relationship between risk premium and the basis. b_1 represents the coefficient for the relationship between spot price change and the basis where b_2 represents the coefficient for the relationship between the risk premium and the basis. $t(b_1)$ and $t(b_2)$ are the t-values from the regression of the basis with spot price change and risk premium respectively. Similarly, R^2_1 and R^2_2 are the R^2 of the regression models of basis with spot price change and the risk premium respectively. Moreover, F_1, DF_1, and F_2, DF_2 shows the F-statistics of the regression models of basis with spot price change and risk premium respectively. The sum of value of coefficients of regressions for each future contract such as 1-month, 3-month, or 6-month must add up to 1 where the sum of intercepts must add up to zero. The total number of price observations within each regression are 217. The level of significance is shown using asterisks as:

* $p < 0.10$

** $p < 0.05$

*** $p < 0.01$

Table 5 shows the results for 6 different regressions, 2 for each future contract of Brent Crude Oil with maturities 1-month, 3-month, and 6-month. The results indicating number 1 with variables a, b, t(b), R, F, DF show the results of the regression which explores the relationship between spot price change and basis where the results with number 2 represent the regression which explores the relationship between risk premium and the basis as it can be seen in equations (3) and (4). Similarly, table 6 shows the results for 4 different regressions, 2 for each future contract of TTF European Gas with maturities 1-month and 2-month. The results indicating number 1 with variables a, b, t(b), R, F, DF show the results of the regression which explores the relationship between spot price change and basis where the results with number 2 represent the regression which explores the relationship between risk premium and the basis as it can be seen in equations (3) and (4). These regressions explore the relationships using basis as the only explanatory variable.

The results in table 5 show that the basis has the information about the forecast of spot prices at the same time it has some information about the presence of risk premium and variations in it as well. The results strongly show that the basis contain information about the forecast of spot price in 1-month future contract with the highly significant coefficient b_1 of 0.938 and the presence of risk premium in 6-month future contract with highly significant coefficient b_2 of 0.848. Overall, the results show that the relationship of basis with spot price and risk premium is highly significant indicating the strong presence of information in the basis about changes in spot price and presence of risk premium and change in risk premium except coefficient b_2 of 1-month future contract of Brent Crude. However, if we look at the R^2 of all six regressions, we come to know that basis can explain the maximum of 7% changes in spot price with $R^2{}_1$ of 1-month future contract at 0.077 and a maximum of 27% changes in the risk premium with $R^2{}_2$ at 0.277 of 6-month future contract. This indicates that there are other factors that explain the changes in spot prices and risk premium in addition to the basis. these results are in line with that of Silvapulle, P., & Moosa, I. A. (1999) have found that the future prices in crude oil markets can forecast the spot prices but with a bidirectional view.

The results in table 6 show that the basis has the information about the presence and variations in risk premium along with the basis of 1-month future contract having the information about the spot price change with no strong evidence. This is similar to the findings of Haff et. al. (2008) who have also found that the 1-month forward contract can forecast the spot prices. The results in table 6 also show that the basis of the 2-month future contract does not have any information about the spot price change with a coefficient b_1 of -0.008 indicating that the price of 2-month future contract cannot forecast the spot price. Additionally, the evidence for the presence of risk premium in both 1- and 2-month future contracts of TTF European Gas is very strong with coefficients b_2 of 0.723 and 1.008 of 1-month and 2-month future contracts respectively. This is in-line with the findings of Haff et. al. (2008) who have found the presence of risk premium in the UK natural gas market. However, like the results in table 5, there is strong evidence that there are other factors that can explain the variations in the spot price and risk premium in TTF European Gas in addition to the basis with basis explaining 6% and 21% of changes in risk premium of 1-month and 2-month contracts respectively. In case of spot price changes, the extremely low $R^2{}_1$ indicates that the relationship between the basis and spot price change must be explored with the addition of various other factors.

The results in table 5 and table 6 are like that of Brooks et. al. (2013) who have found strong evidence that the future price of crude oil and natural gas have forecast power over the future price. However, this study has shown that price of 2-month future contract of TTF Gas cannot explain the changes in the future spot price with a negative coefficient b_1. Additionally, similar to this study, Brooks et. al. (2013) have also found some evidence on the presence of risk premium in both crude oil and natural gas.

Chapter 5

Conclusion

Commodities are one of the top traded assets in the world and to better understand the commodity market and the trading, this study explores the issue of future pricing, more specifically, the difference between the spot and future prices. There are many theories explaining the future pricing of commodities, but this study keenly focuses on the risk premium theory to explore the issue. Additionally, this paper uses Brent Crude and TTF European Gas as commodities for the data input to find out whether the claims about the future pricing made by the risk premium theory hold or not. The analysis has two focuses: first is to test whether future prices have any forecast power over spot prices of the said commodities, second is to test whether there is a risk premium present in the future prices of the considered energy commodities. The results of the analysis have found that the there is strong evidence for the presence of risk premium in the future prices of all the considered contract maturities of 1-month, 3-month, and 6-month of Brent crude. Similarly, there is strong evidence of the presence of risk premium in the future prices of all considered contract maturities of 1-month and 2-month of TTF European Gas. Moreover, the results have also shown significantly that the future prices of all the considered maturities of Brent crude have forecast power over spot prices where on the other hand there is an insignificant and mix outcome on the forecast power of future prices over spot price in case of TTF European Gas.

Therefore, based on these results, to answer the questions that this study aims to answer, strong and consistent results were found in terms of presence of risk premium in both Brent crude and TTF European gas future prices along with the forecast power of the future prices of Brent crude over its spot price.

In addition to the regression results, the results from a concise trend analysis have shown that the risk premium in the Brent crude 1-month future contract is highly volatile and major fluctuations in the times of crisis can be observed in both positive and negative side. On the contrary, the risk premium in TTF European Gas 1-month future contract is stable over time where the only major variation in the risk premium was observed recently starting from 2022 and it leads to 2023 which could be attributed to the recent energy (natural gas) crisis in Europe because of Russian war in Ukraine.

This study, however, is not free from any drawbacks which vary across the data and the regression performed. The data used includes only two commodities, each with a limited number of future contracts maturities. Therefore, the results of this study cannot be applied to other energy commodities in terms of confirming the claims of risk premium theory or any commodity at all for that reason as there could be different findings when other commodities and additional future contracts with different maturities were considered. The regression analysis was performed with “Basis” as the only explanatory variables as there could be other variables which explain the relationship between spot and future prices and it could have changed the results of the analysis as it is quite visible in the low R^2 of the regressions. Additionally, the diagnostic tests indicated the presence of autocorrelation and absence of normality which could have impacted the results of the analysis. Thus, for the future similar analysis, it can easily be suggested to consider commodities in addition to the ones used in this study, consider future contracts with different maturities in addition to the ones considered in this study, and last but not the least, include other explanatory variables such as month fixed effects which can also help explain the relationship between future price and spot price.

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Appendix

A1. Brent Crude Spot price change 1-month future regression

	Dependent variable:
	dS
Basis1	0.938***
	(0.205)
Constant	0.172
	(0.422)
Observations	240
R^2	0.081
Adjusted R^2	0.077
Residual Std. Error	6.528 (df = 238)
F Statistic	20.896*** (df = 1; 238)
Note:	*p<0.1; **p<0.05; ***p<0.01

A2. Brent Crude Spot price change 3-month future regression

	Dependent variable:
	dS
Basis3	0.338***
	(0.127)
Constant	0.197
	(0.433)
Observations	240
R^2	0.029
Adjusted R^2	0.025
Residual Std. Error	6.709 (df = 238)
F Statistic	7.103*** (df = 1; 238)
Note:	*p<0.1; **p<0.05; ***p<0.01

A3. Brent Crude Spot price change 6-month future regression

	Dependent variable:
	dS
Basis6	0.152*
	(0.088)
Constant	0.222
	(0.437)
Observations	240
R^2	0.012
Adjusted R^2	0.008
Residual Std. Error	6.766 (df = 238)
F Statistic	2.961* (df = 1; 238)
Note:	*p<0.1; **p<0.05; ***p<0.01

A4. Brent Crude risk premium 1-month future regression

	Dependent variable:
	RP1
Basis1	0.062
	(0.205)
Constant	-0.172
	(0.422)
Observations	240
R^2	0.0004
Adjusted R^2	-0.004
Residual Std. Error	6.528 (df = 238)
F Statistic	0.092 (df = 1; 238)
Note:	*p<0.1; **p<0.05; ***p<0.01

A5. Brent Crude risk premium 3-month future regression

	Dependent variable:
	RP3
Basis3	0.662***
	(0.127)
Constant	-0.197
	(0.433)
Observations	240
R^2	0.103
Adjusted R^2	0.099
Residual Std. Error	6.709 (df = 238)
F Statistic	27.183*** (df = 1; 238)
Note:	*p<0.1; **p<0.05; ***p<0.01

A6. Brent Crude risk premium 6-month future regression

	Dependent variable:
	RP6
Basis6	0.848***
	(0.088)
Constant	-0.222
	(0.437)
Observations	240
R^2	0.280
Adjusted R^2	0.277
Residual Std. Error	6.766 (df = 238)
F Statistic	92.447*** (df = 1; 238)
Note:	*p<0.1; **p<0.05; ***p<0.01

A7. TTF European gas Spot price change 1-month future regression

	Dependent variable:
	dS
Basis1	0.277
	(0.185)
Constant	-0.111
	(0.887)
Observations	217
R^2	0.010
Adjusted R^2	0.006
Residual Std. Error	12.840 (df = 215)
F Statistic	2.249 (df = 1; 215)
Note:	*p<0.1; **p<0.05; ***p<0.01

A8. TTF European gas Spot price change 2-month future regression

	Dependent variable:
	dS
Basis2	-0.008
	(0.131)
Constant	0.144
	(0.904)
Observations	217
R^2	0.00002
Adjusted R^2	-0.005
Residual Std. Error	12.907 (df = 215)
F Statistic	0.004 (df = 1; 215)
Note:	*p<0.1; **p<0.05; ***p<0.01

A9. TTF European gas risk premium 1-month future regression

	Dependent variable:
	RP1
Basis1	0.723***
	(0.185)
Constant	0.111
	(0.887)
Observations	217
R^2	0.066
Adjusted R^2	0.062
Residual Std. Error	12.840 (df = 215)
F Statistic	15.296*** (df = 1; 215)
Note:	*p<0.1; **p<0.05; ***p<0.01

A10. TTF European gas risk premium 1-month future regression

	Dependent variable:
	RP2
Basis2	1.008***
	(0.131)
Constant	-0.144
	(0.904)
Observations	217
R^2	0.217
Adjusted R^2	0.213
Residual Std. Error	12.907 (df = 215)
F Statistic	59.496*** (df = 1; 215)
Note:	*p<0.1; **p<0.05; ***p<0.01

A11. Brent Crude Spot price change 1-month future regression Durbin-Watson test

Durbin - Watson Test	
Data	R1
DW	1.2304
P-value	8.437e-10
Alternate Hypothesis	true autocorrelation is greater than 0

A12. Brent Crude Spot price change 1-month future regression Breusch-Pagan test

Breusch - Pagan Test	
Data	R1
BP	0.93587
df	1
P-value	0.3333

A13. Brent Crude Spot price change 1-month future regression Shapiro-Wilk Test

Shapiro - Wilk Test	
Data	residuals(R1)
W	0.93948
P-value	2.135e-08

A14. R Script

Libraries:

```
library(tidyverse)
library(openxlsx)
library(tidyr)
library(stargazer)
library(fastDummies)
library(car)
library(corrplot)
library(lmtest)
library(dplyr)
library(tidyverse)
```

```
library(tidyquant)
library(lubridate)
library(tseries)
library(sandwich)
library(plm)
```

Brent crude spot change:

```
R1 <- lm(dS ~ Basis1, data = Brent_Crude)
R2 <- lm(dS ~ Basis3, data = Brent_Crude)
R3 <- lm(dS ~ Basis6, data = Brent_Crude)
stargazer(R1, type = "text", out= "R1.html")
stargazer(R2, type = "text", out= "R2.html")
stargazer(R3, type = "text", out= "R3.html")
```

Brent crude risk premium:

```
R4 <- lm(RP1 ~ Basis1, data = Brent_Crude)
R5 <- lm(RP3 ~ Basis3, data = Brent_Crude)
R6 <- lm(RP6 ~ Basis6, data = Brent_Crude)
stargazer(R4, type = "text", out= "R4.html")
stargazer(R5, type = "text", out= "R5.html")
stargazer(R6, type = "text", out= "R6.html")
```

TTF spot change:

```
R7 <- lm(dS ~ Basis1, data = TTF_gas)
R8 <- lm(dS ~ Basis2, data = TTF_gas)
stargazer(R7, type = "text", out= "R7.html")
stargazer(R8, type = "text", out= "R8.html")
```

TTF risk premium:

```
R9 <- lm(RP1 ~ Basis1, data = TTF_gas)
R10 <- lm(RP2 ~ Basis2, data = TTF_gas)
stargazer(R9, type = "text", out= "R9.html")
stargazer(R10, type = "text", out= "R10.html")
```

Autocorrelation:

dwtest(R1)

dwtest(R2)

dwtest(R3)

dwtest(R4)

dwtest(R5)

dwtest(R6)

dwtest(R7)

dwtest(R8)

dwtest(R9)

dwtest(R10)

Heteroskedasticity:

bptest(R1)

bptest(R2)

bptest(R3)

bptest(R4)

bptest(R5)

bptest(R6)

bptest(R7)

bptest(R8)

bptest(R9)

bptest(R10)

Normality:

shapiro.test(residuals(R1))

shapiro.test(residuals(R2))

shapiro.test(residuals(R3))

shapiro.test(residuals(R4))

shapiro.test(residuals(R5))

shapiro.test(residuals(R6))

```
shapiro.test(residuals(R7))
shapiro.test(residuals(R8))
shapiro.test(residuals(R9))
shapiro.test(residuals(R10))
```

Correlation Matrix:

Brent Crude

```
cmat_Brent <- cor(Brent_Crude[, c(2,3,5,8)],use="pairwise.complete.obs")
print(cmat_Brent)
cmat_Brent_Reg <- cor(Brent_Crude[, c(9,11,14,15,17,20,21)],use="pairwise.complete.obs")
print(cmat_Brent_Reg)
```

TTF European Gas

```
cmat_TTF <- cor(TTF_gas[,2:4],use="pairwise.complete.obs")
print(cmat_TTF)
cmat_TTF_Reg <- cor(TTF_gas[,5:9],use="pairwise.complete.obs")
print(cmat_TTF_Reg)
```