Crude Oil Risk Management: the Optimal Hedge Ratio and Hedging Effectiveness Evolution

Erica Cristina BALEA[1]

ABSTRACT
The main purpose of risk management is to reduce the cash-flows fluctuations of a company. In order to properly manage risks, the estimation of the optimal hedging ratio is needed. This paper analyzes the evolution of the optimal hedge ratio and hedging effectiveness for the Brent crude oil. Also, the relationship between the estimation period and hedge ratio, respective hedging effectiveness is studied. The results show that if the estimation period is increased, the mean and median of the hedge ratio decrease, converging to 1. Also, for longer estimation periods, the volatility of the optimal hedge ratio tends to decrease. It is found a positive relationship between the estimation period and the hedging effectiveness, with important implications on risk management strategies.

KEYWORDS: *hedging effectiveness, optimal hedge ratio, risk management, crude oil.*

JEL CLASSIFICATION *G11, G32*

INTRODUCTION

In the current economic conditions, we can observe that the oil market has continually expanded and turned into a complex financial market and the biggest commodity market in the world. The main risk encountered in the crude oil commodity market refers to the decrease of crude oil production, the unpredictable changes in the global oil demand, the global economic crises risks, the petroleum reserve policy and geopolitical risks.

This paper is focused on the analysis of the evolution of the optimal hedge ratio and hedging effectiveness for the Brent crude oil. Also, the relation between the estimation period and hedge ratio, respective hedging effectiveness is studied. The paper and it is organized as follows: the first section presents the main findings from the existing literature. Section 2 presents the methodology and the database. The third section presents the results, while in the last section the conclusions are given.

1. LITERATURE REVIEW

In the literature, some authors made extensive research on the volatility of crude spot, forward and futures returns using different methodologies: the constant conditional correlation model, the dynamic conditional correlation model, the vector autoregressive moving average and linear diagonal VEC model (Haigh & Holt, 2002; Lanza et al., 2006; Manera et al., 2006). Also, numerous studies found that markets are efficient and price evolution is unpredictable. For example, Boboc and Dinică (2013), using a genetic algorithm, found that the EUR/USD market is efficient and one can not find an optimal trading strategy based on past data.

[1] Bucharest University of Economic Studies, Romania, erica.balea@gmail.com

Carter et al. (2006a, 2006b) analyzed the price behavior of a wide range of oil commodities and found out that not only the prices are highly volatile, but also the levels of volatility themselves are extremely variable.

There are some studies which analyze the correlation of the prices of the various products obtained in refining process of crude oil such as: the evolution of heating oil prices versus kerosene prices (Carter et al., 2004; Gjolberg & Johnson, 1999).

More recent studies are focused on the optimal cross hedging methods (Bertus et al., 2009; Nascimento & Powell, 2008). For exemple, Bertus et al. (2009) states that the optimal cross hedging instrument is based on crude oil. By contrast, other studies found that the usage of crude oil as a cross hedge is not optimal for time prospects of three months or less (Adams & Gerner, 2012). The authors state that for short hedging horizons, gasoil forwards contracts represent the highest cross hedging efficiency for jet-fuel spot price exposure, while for periods of more than three months, the uppermost cross hedging efficiency is represented by WTI and Brent.

Concerning the estimation of the optimal hedge ratio, in a significant number of studies different techniques were examined, such as: ordinary least squares regression (Ederington, 1979), error-correction model (Chou et al., 1996), autoregressive distributed lag model (Chen et al., 2004), GARCH models (Lien et al., 2002; Lee & Yoder, 2007; Power et al., 2013). Furthermore, certain studies focused on examining the hedging ratio on different markets. Armeanu et al. (2013), Dinică (2013a), Balea and Buculescu (2013) and Dowson et al. (2000) focused on the optimal hedging ratio (OHR) for agricultural markets, Dinică (2013b) estimated the OHR for the metals traded at London Metals Exchange using different metodologies, while Power et al. (2013) analyzed the corn and live cattle markets. Also, Dinică and Armeanu (2013) examined the metals market and found that the OLS hedging ratios are constant over different time horizons.

An important study conducted by Daniel (2001) shows that hedging can considerably reduce the volatility of oil price without substantially reducing returns. Also, the author argues that another advantage associated to hedging would be greater predictability and certainty. Balea and Dinică (2013) examined the impact of currency hedging on target costing objectives.

Jalali-Naini and Kazemi-Manesh (2006) analyzed the hedging ratios using the weekly spot prices of West Texas Intermediate oil and futures prices of crude oil contracts for different time horizons from 4 to 16 weeks on NYMEX.

2. METHODOLOGY

In consideration of reducing the risk of spot price fluctuation for a certain underlying asset, the hedger has to trade a certain quantity of futures contract. Let us suppose that an enterprise has a spot position of X_S units. Also, depending on whether the position is long or short, the sign of X_S is positive or negative. For simplifying reasons, we will further consider that the initial spot position is long. In order to hedge this position, the company can take a contrary position on a futures contract. The value of the hedge portofolio (H) is given by:

$$H_t = X_S S_t - X_F F_t \quad (1)$$

Hedging's purpose is to minimize the variance of the change in value of the hedge portfolio, expressed by the following relation:

$$\Delta H_t = X_S \Delta S_t - X_F \Delta F_t \quad (2)$$

The hedging ratio is given by the ratio between the quantity traded on the futures market and the quantity representing the spot exposure: $h = X_F / X_S$. Replacing the hedging ratio expression in the above equation we can obtain:

$$\Delta H_t = X_S(\Delta S_t - h\Delta F_t) \quad (3)$$

Some researchers (Johnson (1960), Stein (1961) and Ederington (1979)) derive the hedging ratio by minimizing the variance of the price change of the hedged portfolio as follows:

$$Var(\Delta H_t) = X_S^2 \left(Var(\Delta S_t) + h^2 Var(\Delta F_t) - 2h\,Cov(\Delta S_t, \Delta F_t) \right) \quad (4)$$

Consequently, by minimizing the variance of ΔH, one can obtain the optimal hedge ratio:

$$h^* = \frac{Cov(\Delta S_t, \Delta F_t)}{Var(\Delta F_t)} \quad (5)$$

It is considered that the simplest way to estimate the optimal hedge ratio is to run the OLS model (Adams and Gerner, 2012), where β is the estimation of h^*.

$$\Delta S_t = \alpha + \beta \Delta F_t + \varepsilon_t \quad (6)$$

The database used is represented by weekly spot and futures prices of Brent crude oil for the period 05.11.1997-31.10.2012. Totally, there are 783 weekly price observations. The day of the week is Wednesday and in the cases when Wednesday is not a business day, the next business day is taken into consideration. The futures price is represented by the nearest to maturity contract, while the spot price is represented by the North Sea specification of crude oil Brent price.

The optimal hedging ratio is estimated for rolling periods of 1, 2, 3, 5, 7, 10 and 12 years by simultaneously augmenting the estimation period with the new data and dropping the first data. The evolution in time of the optimal hedge ratios and their corresponding coefficients of determination is analyzed.

3. RESULTS

The first step of the analysis consists in the examination of the evolution of the spot and futures prices during the period. It can be observed that the spot and futures prices are strongly correlated for Brent. Also, the volatility is high, especially in the second half of the sample.

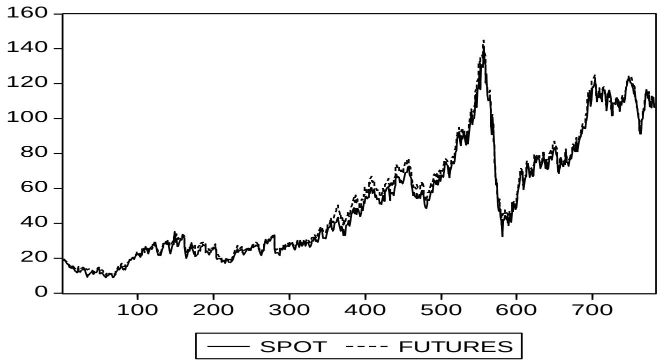

Figure 1. Spot and futures price evolution for Brent

Source: Own calculations using Eviews 4.1

The augmented Dickey-Fuller test shows that both spot and futures prices are unit root process and therefore are non-stationary. The usage of non-stationary series may lead to spurious regressions and invalidate in this way the estimation of the optimal hedge ratio (Cotter & Hanly, 2006). However, the first differences series are stationary and the OLS regression can be estimated on them.

Table 1. ADF unit root test

Brent crude oil		**t stat**	**p value**
Spot	Level	-0.8448	0.8053
	First Difference	-28.9275	0.0000
Futures	Level	-0.7821	0.8231
	First Difference	-28.1012	0.0000
Critical values: 1%: -3.438; 5%: -2.865; 10%: -2.568			

Source: Own calculations using Eviews 4.1

In the Table 2 are synthesized the descriptive statistics of the optimal hedge ratio estimated using different rolling estimation periods. It can be observed that if the estimation period is increased, the mean and median of the hedge ratio decrease, converging to 1. Also, for longer estimation periods, the volatility of the optimal hedge ratio tends to decrease (the standard deviation decreases, as well as the difference between the maximum and the minimum value).

Table 2. Optimal hedge ratio statistics

Estimation period	**1Y**	**2Y**	**3Y**	**5Y**	**7Y**	**10Y**	**12Y**
No. obs in the period	52	104	156	260	364	520	624
Mean	1.0541	1.0542	1.0584	1.0473	1.0314	1.0212	1.0166
Median	1.0342	1.0280	1.0176	1.0124	1.0223	1.0187	1.0178
Max	1.3565	1.2459	1.2177	1.1677	1.1303	1.0454	1.0242
Min	0.9115	0.9515	0.9643	0.9978	0.9998	1.0039	1.0100
St dev	0.0961	0.0817	0.0788	0.0578	0.0315	0.0127	0.0035
No. of hedge ratios	731	679	627	523	419	263	159

Source: Own calculations using Eviews 4.1

Figure 2 illustrates the evolution of the optimal hedge ratio. One can observe that the optimal hedge ratio decreased over the sample period, as well as its volatility. Also, the optimal hedge ratios estimated using smaller estimation periods exhibit the greatest volatility.

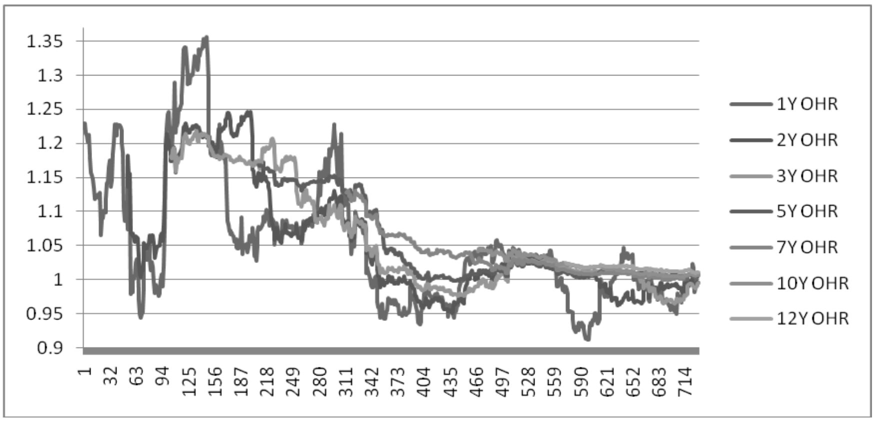

Figure 2. Evolution of the optimal hedge ratio
Source: Own calculations

In the Table 3 are synthesized the descriptive statistics of the hedging effectiveness measured by the coefficient of determination of the OLS regression using different rolling estimation periods. It can be observed that if the estimation period is increased, the mean and median of the hedging effectiveness increase as well. For longer estimation periods, the hedging effectiveness exhibits a lower volatility (the standard deviation decreases, as well as the difference between the maximum and the minimum value).

Table 3. Hedging effectiveness statistics

Estimation period	**1Y**	**2Y**	**3Y**	**5Y**	**7Y**	**10Y**	**12Y**
No. obs in the period	52	104	156	260	364	520	624
Mean	0.8379	0.8433	0.8503	0.8655	0.8804	0.9128	0.9172
Median	0.8689	0.8767	0.8691	0.8755	0.9372	0.9204	0.9171
Max	0.9843	0.9744	0.9668	0.9573	0.9483	0.9384	0.9262
Min	0.5176	0.6029	0.6176	0.7023	0.7339	0.8164	0.9117
St dev	0.1122	0.1055	0.0990	0.0887	0.0734	0.0306	0.0031
No. of hedge ratios	731	679	627	523	419	263	159

Source: Own calculations using Eviews 4.1

Figure 3 illustrates the evolution of the hedging effectiveness. The tendency of the hedging effectiveness to increase with the estimation period is obvious. Also, the hedging effectiveness for the optimal hedge ratios estimated using smaller estimation periods exhibit the greatest volatility.

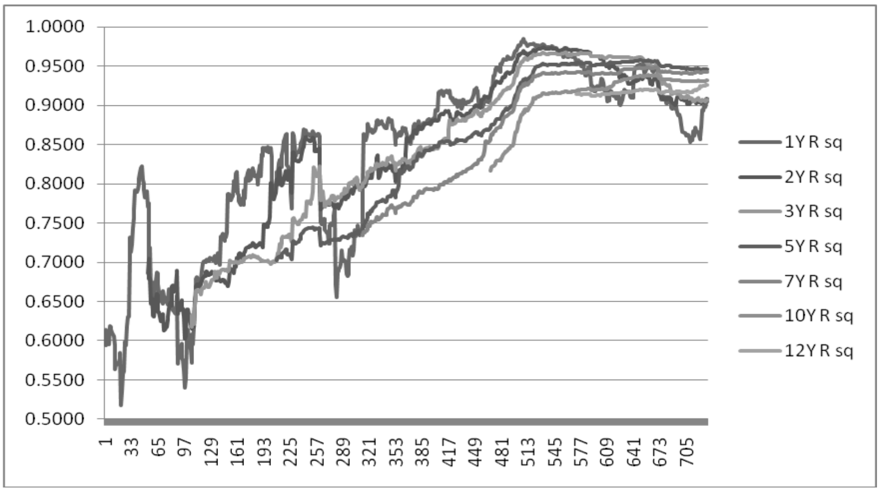

Figure 3. Evolution of the hedging effectiveness
Source: Own calculations

CONCLUSIONS

In the current economic conditions, it can be observed that the oil market has continually expanded and turned into a complex financial market and the biggest commodity market in the world. The main risk encountered in the crude oil commodity market refers to the decrease of crude oil production, the unpredictable changes in the global oil demand, the global economic crises risks, the petroleum reserve policy and geopolitical risks.

I estimated the optimal hedging ratio of the Brent crude oil using rolling periods of 1, 2, 3, 5, 7, 10 and 12 years by simultaneously augmenting the estimation period with the new data and dropping the first data. The evolution in time of the optimal hedge ratios and their corresponding coefficients of determination is analyzed.

The results show that if the estimation period is increased, the mean and median of the hedge ratio decrease, converging to 1. Also, for longer estimation periods, the volatility of the optimal hedge ratio tends to decrease. Also, I find a positive relation between the estimation period and the hedging effectiveness.

The analysis of the evolution of the optimal hedge ratio and hedging effectiveness shows that in the last years the volatility of the hedge ratio and hedging effectiveness decreased and the hedging effectiveness increased. This result shows that for a proper estimation of the optimal hedge ratio, there should be used a more actual dataset instead of a longer period.

ACKNOWLEDGEMENTS

This work was financed through IOSUD ASE (Institution for Doctorate Studies, Academy of Economic Studies).

REFERENCES

Adams, Z., Gerner, M. (2012). Cross hedging jet-fuel price exposure, *Energy Economics*, 34(5), 1301–1309.

Armeanu, D., Istudor, N., & Dinică, M.C. (2013). The Optimal Hedging Ratio for Agricultural Market, *Economic Computation and Economic Cybernetics Studies and Research*, 47(3), 37–52.

Balea, E.C., & Buculescu M.M. (2013). Risk management on agricultural market: the case of Romania, *The 8th International Conference on Accounting and Management Informatics Systems (AMIS 2013)*, 37-50.

Balea, E.C., & Dinică, M.C. (2013). Target costing and risk management, *Actual Problems of Economics*, *149*(11), 281-287.

Boboc, I.A., Dinică, M.C. (2013). An Algorithm for Testing the Efficient Market Hypothesis, *Plos One*, *8*(10), e78177.

Bertus, M., Godbey, J., & Hilliard, J. (2009). Minimum variance cross hedging under mean reverting spreads, stochastic convenience yields and jumps: an application to the airline industry, *Journal of Futures Markets*, *29*(2), 736–756.

Carter, D., Rogers, D., & Simkins, B. (2006a). Does hedging affect firm value: evidence from the US airline industry, *Financial Management*, *35*, 53–86.

Carter, D., Rogers, D., & Simkins, B. (2006b). Hedging and value in the US airline industry, *Journal of Applied Corporate Finance*, *18*(4), 21–34.

Carter, D., Rogers, D., & Simkins, B. (2004). *Fuel hedging in the airline industry: the case study of Southwest Airlines*, Oklahoma State University and Portland State University, Working Paper.

Chen, S.S., Lee, C.F., & Shrestha, K. (2004). An Empirical Analysis of the Relationship Between the Hedge Ratio and Hedging Horizon: A Simultaneous Estimation of the Short- and Long-Run Hedge Ratios, *The Journal of Futures Markets*, *24*(4), 359-386.

Chou, W.L., Fan, K.K., & Lee, C.F. (1996). Hedging with the Nikkei index futures: The conventional model versus the error correction model, *The Quarterly Review of Economics and Finance*, *36*(4), 495–505.

Cotter, J., & Hanly, J. (2006). Revaluating Hedging Performance, *The Journal of Futures Markets*, *26*(7), 677–702.

Daniel, J. (2001). Hedging Government Oil Price Risk, International Monetary Fund, Working Paper 01/185.

Dinică, M.C., & Armeanu, D. (2013). Optimal risk management at metals market, *Actual Problems of Economics*, 145(7), 298-305.

Dinică, M.C. (2013a). Alternative Methods for Estimating the Optimal Hedge Ratio, *International Journal of Advances in Management and Economics*, *2*(5), 183-188.

Dinică, M.C. (2013b). Optimal hedge ratio for non-ferrous metals: in-sample analysis, *The 8th International Conference on Accounting and Management Informatics Systems (AMIS 2013)*, 523-534.

Dowson, P.J., Tiffin, A.L., & White, B. (2000). Optimal hedging ratios for wheat and barley at the LIFFE: a GARCH approach, *Journal of Agricultural Economics*, *51*(2), 147–161.

Ederington, L. (1979). The hedging performance of the new future markets, *Journal of Finance*, *34*(1), 157–170.

Gjolberg, O., Johnson, T. (1999). Risk management in the oil industry: can information on long-run prices be utilized? *Energy Economics*, 21, 517–527.

Haigh, M.S., Holt, M., (2002). Crack spread hedging: accounting for time-varying spillovers in the energy futures markets, *Journal of Applied Econometrics*, *17*, 269-289.

Jalali-Naini, A., Kazemi-Manesh, M. (2006). Price volatility, hedging, and variable risk premium in the crude oil market, *OPEC Review*, *30*(2), 55–70.

Johnson, L.L. (1960). The theory of hedging and speculation in commodity futures: portfolio effects, *Review of Economic Studies*, *27*(3), 139–151.

Lanza, A., Manera, M., & McAleer, M., (2006). Modeling dynamic conditional correlations in WTI oil forward and future returns, *Finance Research Letters*, *3*(2), 114–132.

Lee, H.-T., & Yoder, J.K. (2007). A bivariate Markov regime switching GARCH approach to estimate time varying minimum variance hedge ratios, *Applied Economics*, *39*(10), 1253–1265.

Lien, D., & Tse, Y.K. (2002). Some recent developments in futures hedging, *Journal of Economic Surveys*, *16*(3), 357–396.

Manera, M., McAleer, M., & Grasso, M. (2006). Modelling time-varying conditional correlations in the volatility of Tapis oil spot and forward returns, *Applied Financial Economics*, *16*(7), 525–533.

Nascimento, J., & Powell, W. (2008). An optimal solution to a general dynamic jet fuel hedging problem, Princeton University, Working Paper

Power, G.J., Vedenov, D.V., Anderson, D.P., & Klose, S. (2013). Market volatility and the dynamic hedging of multi-commodity price risk, *Applied Economics*, *45*, 3891–3903.

Stein, J.L. (1961). The simultaneous determination of spot and futures prices, *American Economic Review*, *51*, 1012–1025.