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OPTIMAL RISK MANAGEMENT AT METALS MARKET

The main purpose of risk management is to smoothen the expected cash flows of a company. In order to realize a proper hedging, the estimation of the optimal hedging ratio is needed. Our paper analyses the optimal hedging ratio for the most traded non-ferrous metals: aluminum and copper. In line with the existing literature, our results show that the optimal hedging ratio increases with the hedging horizon, converging to 1 for longer tenors. Also, the hedge ratios are constant over different estimation periods.

Keywords: *risk management, hedging, optimal hedge ratio, OLS.*

JEL classification: *G15, G32.*

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ОПТИМАЛЬНЕ УПРАВЛІННЯ РИЗИКАМИ НА РИНКУ МЕТАЛІВ

У статті показано, що головна мета управління ризиками — згладжування очікуваних грошових потоків компанії. Для реалізації якісного хеджування необхідне оцінювання його оптимальних показників. Проаналізовано оптимальне співвідношення хеджування для кольорових металів: алюмінію і міді. Відповідно до попередніх досліджень наші результати показали, що оптимальне співвідношення хеджування збільшується з підвищенням горизонту хеджування і підходить до одиниці в триваліших термінах. Крім того, співвідношення хеджингу постійні протягом різних періодів оцінки.

Ключові слова: *управління ризиками, хеджування, оптимальне співвідношення хеджування, метод найменших квадратів.*

Таб. 6. Фор. 8. Літ. 19.

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ОПТИМАЛЬНОЕ УПРАВЛЕНИЯ РИСКАМИ НА РЫНКЕ МЕТАЛЛОВ

В статье показано, что главная цель управления рисками — сглаживание ожидаемых денежных потоков компании. Для реализации качественного хеджирования необходима оценка его оптимальных показателей. Проанализировано оптимальное соотношение хеджирования для наиболее торгуемых цветных металлов: алюминия и меди. В соответствии с предыдущими исследованиями наши результаты показали, что оптимальное соотношение хеджирования увеличивается с повышением горизонта хеджирования и стремится к единице в более длительных сроках. Кроме того, соотношения хеджинга постоянны в течение различных периодов оценки.

Ключевые слова: *управление рисками, хеджирование, оптимальное соотношение хеджирования, метод наименьших квадратов.*

Introduction. The main purpose of risk management is to smoothen the expected cash flows of a company. Puzyryova (2010) shows that hedging is one of the most important strategies to counteract financial risks. The most straightforward way of conducting efficient risk management is through financial hedging with derivatives. A company has a variety of instruments for hedging, starting with forward and futures contracts and ending with exotic options and structures. The most used and easiest

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way of risk management is hedging through futures or forward contracts because of the linearity in the payoff for these instruments. In this case, the hedging operation supposes combination of the spot position with a contrary position on a future or on a forward contract. The widest spread recommendation in respect with this type of hedging is to transact a financial derivative with notional equal with the exposed amount, that is, the use of a unitary hedging ratio. But this rule is not the result of solving an optimality problem, so it can't provide optimal hedging. In the literature, the optimal hedging ratio appears as being risk-minimizing or utility-maximizing. The risk-minimizing models estimate the hedging ratio by minimizing a certain risk measure, such as variance (Johnson, 1960; Ederington,1979; Myers and Thompson, 1989) or the generalized semivariance (De Jong et al.,1997; Lien and Tse,2000). The models focused on the maximization of the utility use specific utility functions of return and risk, discussed in Cecchetti et al. (1988), Kolb and Okunev (1993) and Hsin et al. (1994).

In order to estimate the optimal hedge ratio, the following methods were used: ordinary least squares regression (Ederington (1979), Benninga et al. (1984)), error correction models (Chou et al. (1996), Sim and Zurbruegg (2001)), conditional heteroscedastic methods (ARCH and GARCH: Cecchetti et al. (1988), Baillie and Myers (1991), Floros and Vougas (2004)) and the cointegration models (Geppert (1995), Chou et al (1996)). Chen et al. (2004) proposed a version of the error-correction models, based on the simultaneous equations models considered by Hsiao (1997) and Pesaran (1997), obtaining a joint estimation of the short- and long-run hedging ratios. According to Lee and Chien (2010), various econometric models provide different conclusions when estimating the optimal hedge ratio.

Our paper estimates the optimal hedge ratio for the most traded non-ferrous metals on the London Metals Exchange, aluminum and copper, using the ordinary least squares regression. The London Metals Exchange (LME) is the largest exchange for transactions with futures and options having as underlying non-ferrous metals. The metals traded on LME are: aluminum, copper, lead, zinc, tin, nickel, steel, cobalt and molybdenum. At the beginning of the exchange, in 1877, only copper was traded. Lead and zinc were added soon, but they are officially traded since 1920. The new metals added for trading after the World War II are: aluminum (1978), nickel (1979), tin (1989), aluminum alloy (1992), steel (2008), cobalt and molybdenum (2010). The total value of the trades from 2011 was approximately 11.600 bln USD. The most actively traded metals in 2011 are aluminum (over 59 mln futures contracts) and copper (over 34 mln futures contracts), both totalizing more than 68% of the LME's futures turnover. The size of a future contract varies from 5 tons to 25 tons, depending on a traded metal. The prices are expressed in USD/ton and the maximum maturity of a futures varies between 15 and 123 months.

Because aluminum and copper count for more than 2/3 of the traded volume on the LME, we consider them relevant for the non-ferrous metals market in our analysis. We show that the optimal hedge ratio increases with hedging horizon length and is converging to 1 for longer tenors. Also, hedging effectiveness increases with hedging horizon length. The variation of the hedging ratios using different estimation periods is analyzed. The remainder of the paper is organized as follows. The second section provides a description of the methodology used and the database. In the third section are discussed the empirical results, while in the last section the conclusions are given.

Methodology. In order to reduce the variations of the value of a spot position is necessary to combine it with a contrary position taken on a futures contract. Let's consider an economic agent that has a spot position of Q_s units. If the position is long, the sign of Q_s is positive and if the position is short, than the sign of Q_s is negative. For simplifying reasons, we will further consider that the initial spot position a long. In order to hedge this position, the agent can take a contrary position Q_F on futures contract. The value of the hedge portofolio (V_h) is given by:

$$V_h = Q_S S_t - Q_F F_t$$

The objective of hedging is to minimize the variance of the change in value of the hedge portfolio, that is, the variance of ΔV_h.

$$\Delta V_h = Q_S \Delta S_t - Q_F \Delta F_t$$

The above equation can also be written as:

$$\Delta V_h = Q_S (\Delta S_t - h \Delta F_t)$$

and $h=Q_F/Q_S$ represents the hedging ratio.

Johnson (1960) derives the hedging ratio by minimizing the variance of the price change of the hedged portfolio as follows:

$$Var(\Delta V_h) = Q_S^2 [Var(\Delta S_t) + h^2 Var(\Delta F_t) - 2h Cov(\Delta S_t, \Delta F_t)]$$

By solving the optimal problem, that is, minimizing the variance of ΔV_h, we obtain the optimal hedge ratio:

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

In practice, the estimation of the optimal hedge ratio is needed. The simplest way to estimate the optimal hedge ratio is to run the OLS model, where β is the estimation of h^*.

$$\Delta S_t = \alpha + \beta \Delta F_t + \varepsilon_t$$

The database used for the analysis is represented by the daily cash and futures prices of the most traded non-ferrous metals on the London Metals Exchange (LME) during the period 01.06.1998 — 31.05.2012. For each metal (aluminum and copper) and for each type of price (cash or futures) there are 3.535 observations used. The futures price is represented by the nearest-to-maturity contract price, while for the cash price is used the LME official settlement price, both expressed in USD/ton.

Also, in order to compute the optimal hedge ratio for different hedging horizons we matched the data frequency with the hedging horizon. For example, in order to compute the 1 week hedging ratio we used weekly data and for computing the 1-day hedging ratio we used daily data. By applying this methodology we avoid the problems associated with data overlapping, like the existence of autocorrelated error terms in the regression. A detailed description of this issue can be found in Chen et al. (2004).

The sample size of our study allowed us to use non-overlapped data in order to compute the hedging ratio for 6 different hedging horizons: 1 day, 1 week, 3 weeks, 5 weeks, 7 weeks and 9 weeks.

Empirical results. The main objective of the paper is to estimate the optimal hedging ratio by applying the model described above for the non-ferrous metals market on the analyzed period and to quantify the impact of the hedging horizon on the optimal hedging ratio and on the hedging effectiveness.

As shown in the literature, the OLS model can be applied only if the 2 data series (cash and futures prices) are unit root processes and are cointegrated. For testing the unit root hypothesis was applied the augmented Dickey-Fuller (ADF) test and for testing the cointegration was used the Johansen cointegration test.

The ADF test results show that all the prices of the 2 metals analyzed are unit root processes and are integrated of order 1.

Table 1. **Stationarity tests**

ADF test		t-stat	p-value
Aluminum	Cash	-1.8453	0.3587
	First Diff	-66.0963	0.0001
Copper	Cash	-0.9142	0.7843
	First Diff	-63.0654	0.0001
Critical values: 1%: -3.432; 5%: -2.862; 10%: -2.567			

Source: Authors calculations.

The Johansen test provides evidence that cash prices and futures prices series are cointegrated for each metal's case. These results show that the discussed model can be successfully applied for computing the optimal hedge ratio.

Table 2. **Johansen cointegration test**

Metal / Hypothesis	No cointegrating vector	At most one
Aluminum	342.3883	3.1782
Copper	466.2595	0.968
Critical values: None: 1%: 20.04; 5%: 15.41; At most one: 1%: 6.65; 5%: 3.76		

Source: Authors' calculations.

By applying the OLS model on the entire database analyzed we obtained the following results:

Table 3. **Optimal hedging ratio estimated for the entire period**

	Aluminum		Copper	
	Hedge ratio	Adj. R^2	Hedge ratio	Adj. R^2
1D	0.4428	0.2290	0.4919	0.2676
1W	0.8811	0.7272	0.8693	0.8083
3W	0.9741	0.9307	0.9478	0.9285
5W	1.0066	0.9576	0.9869	0.9695
7W	0.9870	0.9664	0.9896	0.9776
9W	0.9656	0.9701	0.9740	0.9728

Source: Authors' calculations.

The results show that the estimated optimal hedging ratio is significantly lower than the naïve hedging ratio of 1 for the short hedging horizons. If for the one-day hedging horizon, the hedging ratio is slightly below 0.5 for the both analyzed metals, it increases with the length of the hedging horizon. For the 1 week hedging horizon, the hedge ratio is near 0.90, continuing to increase for longer tenors, converging to one. Important to notice is that for hedging horizons up to 3 weeks, the optimal hedging ratio is significantly lower than 1 for both metals. Also, it can be observed that the adjusted coefficient of determination is increasing with hedging horizon length, showing a higher effectiveness of the hedging done for longer term exposures. In order to scientifically test for the impact of the length of the hedging horizon on the optimal hedge ratio and on the hedging effectiveness, 2 regressions are used, the endogenous term being the hedging ratios estimated above, respective the adjusted obtained and the exogenous term being the length of the hedging horizon, expressed in weeks. More specifically, the regressions used are:

$$\beta_i = a + bT_i + e_i$$

$$Adjusted\ R_i^2 = a + bT_i + e_i,$$

where T_i is the hedging horizon, expressed in weeks.The results are shown below.

Table 4. **Relation between hedging horizon and hedging ratio, respective adjusted R²**

	Hedging horizon - β	Hedging horizon – adjusted R^2
b	0.0405	0.0606
R^2	0.4595	0.5315

Source: Authors' calculations.

In both cases, the coefficients of the hedging horizon length are positive and strongly significant, showing that the optimal hedge ratio and the hedging effectiveness increase with the hedging horizon.

Next, we focus on the analysis of the evolution of the optimal hedging ratio in respect with the period used for the estimation. In order to observe the changes in the optimal hedge ratio caused by the modification of the period analyzed, we re-estimated, following the same methodology described before, the optimal hedging ratio for each hedging horizon and metal, using this time different periods for the estimation. 1st period analyzed is the same used before: the entire database, 14 years long. The 2nd period is represented by the first 10 years from our database, the 3rd period covers the first 7 years from the database, while the 4th period represents only the first 5 years. We also used for estimation the following periods: starting from the beginning of the 6th year to the end of the 10th year, from the beginning of the 11th year to the end of the 15th year and from the beginning of the 8th year to the end of the 15th year (the second half of the database). The regressions were estimated for each metal and for each hedging horizon, resulting a total of 84 hedging ratios. The results are synthetized in the following 2 tables (one for each metal). On the left side of the table it appears the period that the estimation was done for. The interval of the period is expressed using the first rounded up integer year of the begining of the period and the last rounded up integer year used. As an example, the second period from the table (1-10) is between the begining of the first year of the sample and the end of the 10th year of the sample.

Table 5. **Optimal hedging ratios estimated for aluminum**

Period/ Tenor	Aluminum					
	1D	1W	3W	5W	7W	9W
1-14	0.443	0.881	0.974	1.007	0.987	0.966
1-10	0.414	0.892	0.989	0.995	0.942	0.968
1-7	0.524	0.897	1.015	1.022	1.056	1.041
1-5	0.455	0.922	1.037	1.013	1.036	1.120
6-10	0.407	0.936	0.965	0.982	0.958	0.984
11-14	0.489	0.897	0.964	0.997	0.971	0.958
8-14	0.430	0.878	1.040	1.005	1.012	1.009
Average	0.452	0.900	0.998	1.003	0.995	1.007
St. dev.	0.04	0.02	0.03	0.01	0.04	0.06

Source: Authors calculations.

Table 6. **Optimal hedging ratios estimated for copper**

Period/ Tenor	Copper					
	1D	1W	3W	5W	7W	9W
1-14	0.492	0.869	0.948	0.987	0.990	0.974
1-10	0.414	0.854	0.973	0.961	0.957	0.980
1-7	0.520	0.904	0.967	0.966	1.041	1.001
1-5	0.474	0.891	0.969	0.900	1.025	1.006
6-10	0.411	0.856	0.990	1.002	1.033	1.073
11-14	0.559	0.891	0.963	1.002	1.029	1.005
8-14	0.491	0.868	1.005	0.998	1.000	0.989
Average	0.480	0.876	0.974	0.974	1.011	1.004
St. dev.	0.05	0.02	0.02	0.04	0.03	0.03

Source: Authors calculations.

The results show that the estimated hedging ratios through OLS method are generally constant over time. The changes in the period used for estimation does not cause great modifications of the estimated optimal hedging ratio. A higher volatility appears in the case of smaller periods used for estimation (up to 5 years), but as said before, the changes are not drastic. In the case of the long periods used for estimation, the changes in the hedge ratio are indeed very small. Also, the estimated hedge ratio using the entire database is very close to the average. These findings show that in order to obtain robust estimation of the optimal hedging ratio, a longer analyzed period is needed. Also, our estimations, made for a very long database, are robust.

Conclusions. The main purpose of risk management is to smooth the expected cash-flows of a company. The most straightforward way of conducting efficient risk management is through financial hedging with derivatives. From the great variety of hedging instruments that a company can use, the easiest and most used way of risk management is the hedging through futures or forward contracts because of the linearity in the payoff for these instruments. In order to achieve an efficient hedging strategy, the estimation of the optimal hedging ratio is needed. The literature identifies different estimation techniques, ranging from very simple to complex ones: OLS, error-correction models, conditional heteroscedastic, or the cointegration method. The most used models for estimating the optimum hedge ratio are those based on the ordinary least squares technique.

Using a long and actual database, our paper estimates the optimal hedging ratio for the most traded non-ferrous metals on the London Metals Exchange, aluminum and copper. Our estimation is based on the ordinary least squares regression. We show that the optimal hedge ratio increases with hedging horizon length and is converging to 1 for longer tenors. For hedging horizons up to 3 weeks, the optimal hedging ratio is significantly lower than 1 for both metals. Also, the hedging effectiveness increases with hedging horizon length, proved by the fact that the adjusted coefficient of determination is increasing with hedging horizon length.

The variation of the hedging ratios using different estimation periods is also analyzed. The results show that the estimated hedging ratios through OLS method are generally constant over time. The changes in the period used for estimation does not cause great modifications of the estimated optimal hedging ratio. Indeed, a higher volatility appears in the case of smaller periods used for estimation (up to 5 years), but as said before, the changes are not drastic. In the case of the long periods used for estimation, the changes in the hedge ratio are indeed very small. Also, the estimated hedge ratio using the entire database is very close to the average. These findings show that in order to obtain robust estimation of the optimal hedging ratio, a longer analyzed period is needed. Also, we can conclude that our estimations, made for a very long period database, are robust.

The paper contributes to the literature by providing the estimation of the optimal hedging ratio for aluminum and copper using a long and actual database and by providing an analysis of the impact of estimation period on the estimated hedge ratio. The findings of this paper can be useful for companies exposed to changes in the prices for non-ferrous metals, providing the estimation of the optimal hedging ratio and the methodology for this estimation.

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