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RISK MANAGEMENT ON THE METALS MARKET

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Abstract: The purpose of this paper is to attempt to classify risk which can be observed when one deals with data from the metals market. Usually the general definition of risk includes two dimensions. The first one is the probability of occurrence and the second one are the associated consequences of a set of hazardous scenarios. In this research the authors try to add a new dimension: the source of risk, which can be defined in terms of the level of turnover (volatility of volume) and price (volatility of returns). One can categorize risks in terms of multidimensional ranking based on a comparative evaluation of the consequences, probability, and source of a given risk. Another dimension is the chosen risk measures, in the meaning of the risk model. In risk analysis, some selected quantile risk measures were proposed: VaR, Expected Shortfall, Median Shortfall and GlueVaR. The empirical part presents a multidimensional risk analysis of the metal market.

Keywords: risk measure, modified GlueVaR, extreme risk, sources of risk, metals market.

1. Introduction

The concept of risk is usually related to the wide range of areas of human activity. The decision-making process is related to the risk which reflects the expectations of the decision-maker. Usually the risk arises when these expectations differ from the reality. Dealing in risky conditions is the fundamental part of any economy. It is worth noting that the problem of risk often causes the decision-maker to have negative thoughts or emotions. This is mainly due to the uncertainty associated with the undertaken actions. In the literature there are mentioned two main approaches to the concept of risk (Jajuga, 2009): the negative and neutral approach. The negative approach assumes that the decision-maker has, in fact, realized his/her decision at a level below his/her expectations. In turn, the neutral approach assumes that the actual realization of the decision does not differ from his/her expectations.

Risk assessment and investor's attitude towards risk are related to risk management, which represents all activities, methods and tools that allow for a proper understanding of its sources, manner of arising and potential consequences. Risk management is related to the decision-making process and to the identification of tools which help to reduce risk, as well as to the construction of any strategy allowing for its monitoring and reporting (Christoffersen, 2012).

2. Definition of risk

It is difficult to define risk, but most often it is associated with the probability of incurring some loss. In this paper, risk relates to the loss from the undertaken investment and is considered as an objective and quantifiable phenomenon. It is often indicated that "the probability of incurring a loss/damage" is independent of the decision-maker (investor). Risk creates opportunities for success, but at the same time it threatens the implementation of the undertaken tasks. In investment activity, risk is a tool to obtain certain benefits, but it is verified by potential losses that are related to the undertaken activity (Frankel, Hommel, and Rudolf, 2005). An interesting definition of risk is the one that indicates the lack or the inadequacy of information as its source. The definition of risk based on this criterion was proposed by Kreim (1988). From his point of view, risk means that all decisions made due to incomplete information are not optimal in terms of the adopted goal. A similar definition of risk is proposed by Holscher (1987), stating that the risk is a threat of failure to achieve the assumed level of profit due to having incomplete information. The problem of incomplete information that participants of economic processes have at their disposal, often appears as the main factor creating risk.

Risk is also associated with volatility, i.e. variability within the set of the realized values of the analysed process. The variability is measurable, and the variance (or standard deviation) is often the measure of such variation. Generally, it can be said that from a quantitative point of view, the measure assessing risk is a mapping of the space of events that generate risk on a numerical space (most often a set of real numbers). It is worth emphasizing that not every mapping of this type is a measure of risk. Artzner et al. indicated a set of axioms that should meet the so-called 'good' measure of risk (Artzner, Delbaen, Eber, and Heath, 1999). These axioms are positive homogeneity, monotonicity, translation invariance and subadditivity. The risk measure satisfying the above axioms is called coherent risk measure.

3. Dimensions of risk

It is obvious that every activity in the economic world generates different risks. Nevertheless, one may indicate an unambiguous set of dimensions that define risk regardless of the area of analysis. The first dimension is the probability of the occurrence of a risky event. Two general risks can be identified in the literature: regular risk and extreme risk (Jajuga, 2009). In the context of undertaken investment activities, it is worth focusing on the latter. Extreme risk is characterized by a very low probability of occurrence and is generated by rare events, such as various types of ecological disasters, epidemics, natural disasters, weather anomalies, political events, etc. Considering these rare events, it is often possible to assess with more or less precision, the probability of their occurrence or not. For example, it seems unlikely that an earthquake will occur in a part of the globe with little seismic activity (in this case, such an event will be very unlikely, even rare), while the same event observed in an area of the earth with high seismic activity will be normal, which can be expected with a much higher probability.

In the case of extreme risk analysis, the theory of extreme events and the so-called extreme statistics play a special role. Extreme statistics help us to estimate various parameters that can be used to define rare events and these parameters are e.g. quantiles of empirical distributions of examined phenomena or parameters defining periods, in which the analysed processes take some extreme values (Gumbel, 2004). In terms of economics, there are many examples of events that have caused various types of drastic changes in the market, e.g. Black Thursday (24 Oct 1929), Black Monday (19 Oct 1987), the World Trade Center (11 Sept 2001), the recent financial crisis (2008-2009), the crisis on the crude oil market (2014), and the current crisis caused by the COVID-19 coronavirus pandemic (March 2020 until now).

The likelihood of the occurrence of a risky event is also related to the issue of uncertainty, i.e. the lack of knowledge about an interesting event in the future. There are two types of uncertainty in the literature: endodoxastic and metadoxastic uncertainty (Hansson, 2006). The first type of uncertainty is the result of the randomness of the world around us and the limitations of the human mind in its understanding. It can be expressed using the appropriate probabilistic model. In turn, metadoxastic uncertainty represents the degree of trust that the researcher has for the statistical model which assesses the probability of occurrence of a risky event, in other words, if the model is correct. Endodoxastic uncertainties are included in quantitative risk analysis, while metadoxastic uncertainties not (Gardoni, Reinschmidt, and Kumar, 2007).

The second dimension, directly related to the likelihood of occurrence of risky event, is the consequences of a set of hazardous scenarios. The consequences of risky events can be considered in many aspects (Gardoni and Murphy, 2014):

- type of consequences,
- magnitude of consequences,

- duration of consequences,
- whose consequences matter,
- fraction of consequences.

Considering the first aspect, i.e. the type of consequences, one should consider which ones are important from the point of view of the problem being analysed. It is obvious that part of the effects of risky events is irrelevant, but one should identify and analyse those that may turn out to be significant now or in the future. Another issue is the range of effects of risky events, which can be defined in the context of the quantitative extent of the damage after the occurrence of a risk event and the quality of that damage. Many events generate damage qualitatively poorly, while the extent of this damage in the context of its quantity (range, financial consequences) may be significant. Risky events generate consequences that vary over time. The further into the future, the greater the uncertainty about the impact of such events on reality. One can indicate events whose consequences are short-term, as well as those which are long-term. Time is extremely important from the point of view of repair policy. Short-term effects seem to be easier to repair than those that concern the further future. The consequences of risky events also apply to related units (individuals, institutions, etc.). It is worth paying attention to the recipient of their effects. Naturally, one can indicate some factors that allow to determine the degree of damage impact per unit, this means irrelevant, significant or catastrophic consequences. It is also important to define the population of recipients in terms of its characteristics, such as geographical area or various socio-demographic characteristics. The last problem raised in relation to the effects of risky events is their distribution within the population. The effects of damage can be evenly and fairly distributed across the population, but it can also be a situation that these effects are unfairly distributed. In general, it can be said that the optimal solution is when the consequences are fairly distributed across the population.

The dimensions mentioned above are not always sufficient to fully understand the real essence of risk. Therefore, the proposal is to include an additional category – the source of risk (Gardoni and Murphy, 2014). A source of risk is understood as something that causes it, or helps to maintain it in a controlled manner. From the point of view of the source of risk, one can emphasize its causal nature. The factors generating risk can be indirect or direct, and dependent or independent of an individual. Independent reasons are often difficult to recognize and are often beyond the control of the individual, while direct reasons will not occur without our actions and one can control them. However, indirect reasons also result from our actions, but are beyond our control. In the case of causes dependent on us, it is worth mentioning that one can take into account the scope of responsibility for risky activities. The risk may also be voluntary or involuntary (Cranor, 2007). If the risk is voluntary, it means that one can understand it and be able to control it. All decisions related to risk must be conscious and result directly from the knowledge of its nature. In the event of an involuntary risk, the individual is unaware of dealing with a risky situation, and is not able to predict in any way the consequences of a risky event.

If the source of risk is considered, one should also take into account the issue of who is the creator and who is the recipient of the damage resulting from the implementation of a risky event (Garner, 2009). The recipient of risk and the creator may be the same person, and then we deal with self-imposed risk. However, sometimes the risk recipient is not the same person who generated that risk. Then one can talk about the risk imposed by others. When risk is generated and received by the same person, it seems to be more controlled. Unfortunately it is not. It happens that the risk is created unconsciously, and therefore the uncertainty about the consequences increases. In turn, when we deal with another risk recipient, we often do not focus so much on its consequences, because they do not always directly concern us. One can also find the subjective aspect of risk assessment.

In a further part of this paper, an attempt to identify and classify the risk on the metals market was made. This market, in terms of risk analysis for precious and non-ferrous metals, has been widely examined and described by Krężołek (2016) and Krężołek and Trzpiot (2017a, 2017b). As presented in the previous section, not only the probability of occurrence of a risky event and its consequences were taken into account, but also the source of risk, and as the source of risk the authors proposed the level of turnover.

4. Empirical analysis of the metals market

In this part of the paper the authors applied the theory mentioned in the previous sections into practice. The empirical study was conducted on the base metals market. The main goal was, on the one hand, to indicate the level of risk in relation to various measures, and on the other hand, an attempt to classify risk in the context of these three dimensions discussed in the theoretical section. The dataset consists of daily spot prices (USD / Mt) of base metals (zinc, lead, tin, nickel, aluminum and copper) for data listed on the LME in the period: January 2010 – May 2018. The daily log-returns were calculated. Additionally, the volume of trading on a given trading day (Mt) was used. The measurement of risk was based on four quantile risk measures: VaR, ES, MS and modified GlueVaR. As the probability level of the occurrence of a risky event, the quantiles of empirical distribution of log-return of the analysed assets were used (at the level of 0.05, 0.01 and 0.001).

The risk measures mentioned above are termed in the literature as quantile risk measures, and allow to estimate the return at any point in the distribution, in particular in its tail (extreme returns). Among quantile risk measures, VaR, defined as the α – quantile of the distribution of returns, plays a special role. Value at Risk determines the amount of potential loss that may result from the undertaken investment in a given time horizon and with a fixed tolerance level $1 - \alpha$. However, VaR has one significant disadvantage – it is not a coherent risk measure. This measure does not meet the axiom of subadditivity, i.e. the assumption that the total risk of the investment is not greater than the sum of the individual risks that make up this investment (Artzner et al., 1999). Therefore, two other quantile measures of risk were proposed (Kou and Peng, 2014): Expected Shortfall and Median Shortfall, calculated using formulas:

$$ES_\alpha = CVaR_\alpha = E(r_t | r_t > VaR_\alpha),$$
$$MS_\alpha = Median(r_t | r_t > VaR_\alpha).$$

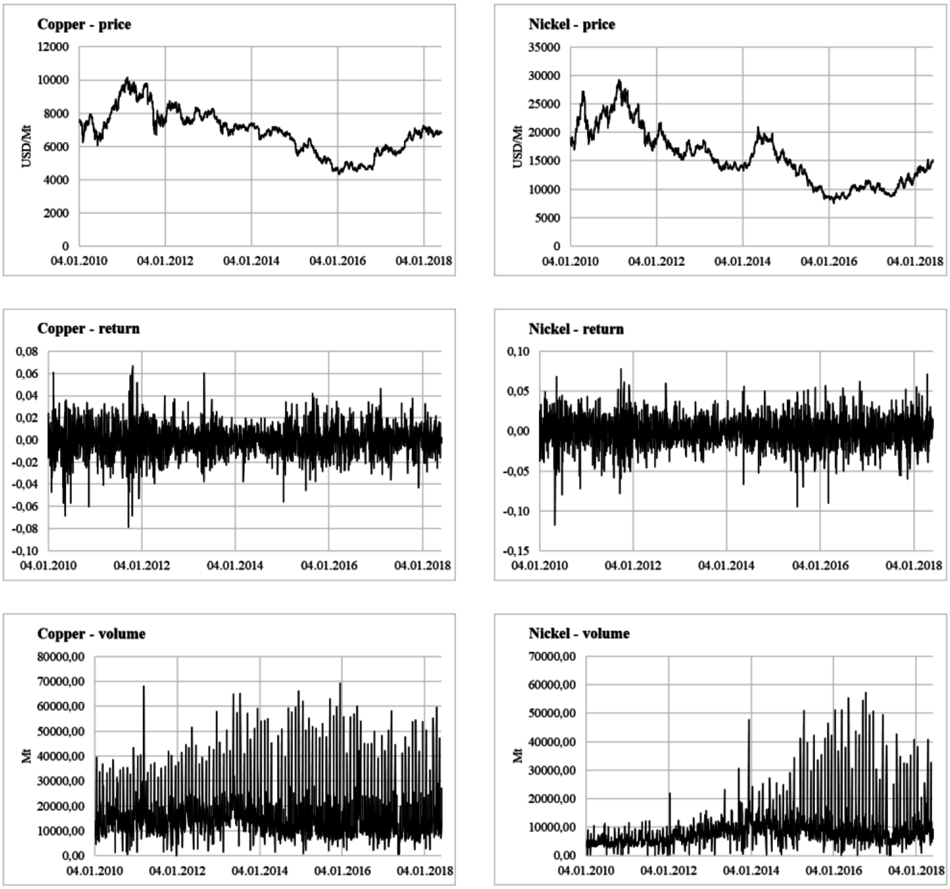

Fig. 1. Time series of price, return and volume for copper (left) and nickel (right) for the period January 2010 – May 2018

Source: own calculations.

A certain generalization of VaR and ES was proposed by Belles-Sampera et al. (2014) – the GlueVaR risk measure, which is their linear combination expressed as:

$$GlueVaR_{\beta,\alpha}^{\omega_1,\omega_2}(X) = \omega_1 CVaR_\beta + \omega_2 CVaR_\alpha + (1 - \omega_1 - \omega_2) VaR_\alpha,$$

where α, β stand for the confidence levels such as $0 < \alpha \leq \beta < 1$, and ω_1, ω_2 are weights related to the subjective importance given by the investor towards risky events. The GlueVaR measure fulfils all assumptions of the coherent risk measure. In this paper the authors decided to modify it by eliminating the element associated with the VaR measure, obtaining as a result:

$$mGlueVaR_{\beta,\alpha}^{\omega_1,\omega_2}(X) = \omega_1 CVaR_\beta + \omega_2 CVaR_\alpha.$$

The formula above, as it results from the condition $\omega_1 = 1 - \omega_2$, also fulfills the assumptions of the coherent risk measure and indicates the average level of risk for the two scenarios of occurrence of the extreme event at the confidence level α and β.

The graphs (Figure 1) show time series of price, returns and volume on the example of copper and nickel.

One can easily see that the periods 2010-2012 and 2017-2018 are characterized by a high level of volatility of both prices and returns. This finding applies to all analysed base metals. In the Table 1 the descriptive statistics for the analysed metals are presented.

Table 1. Descriptive statistics for prices, returns and volume of base metals for the period January 2010 – May 2018

Prices						
Statistics	Zinc	Lead	Nickel	Tin	Aluminium	Copper
Mean	2216.71	2118.52	15643.79	20738.65	1955.83	6884.79
Standard Deviation	435.57	265.92	4977.90	3586.22	280.49	1310.10
Kurtosis	0.91	–0.53	–0.51	1.18	–0.23	–0.45
Skewness	1.16	0.17	0.49	0.72	0.45	0.10
Min	1454.50	1529.00	7561.50	13295.00	1425.50	4327.50
Max	3606.00	2924.50	29281.00	33265.00	2785.50	10179.50
Returns						
Statistics	Zinc	Lead	Nickel	Tin	Aluminium	Copper
Mean	0.00009	0.00001	–0.00009	0.00009	0.00002	–0.00003
Standard Deviation	0.0162	0.0171	0.0191	0.0141	0.0128	0.0138
Kurtosis	2.237	2.166	1.9523	3.811	2.7309	2.6747
Skewness	–0.1262	–0.1641	–0.2894	–0.3687	–0.0623	–0.1071
Min	–0.0826	–0.0856	–0.1179	–0.0993	–0.0782	–0.0781
Max	0.0994	0.0741	0.0779	0.0702	0.0639	0.0667

Volume						
Statistics	Zinc	Lead	Nickel	Tin	Aluminium	Copper
Mean	10 999.77	5 695.27	8 265.13	1 643.78	2 6673.69	1 4645.67
Standard Deviation	6 340.40	2 715.83	5 758.99	881.05	2 8930.30	8 925.94
Kurtosis	13.00	5.03	23.18	1.49	28.95	10.01
Skewness	2.56	1.34	4.03	1.13	4.88	2.81
Min	102.00	2.00	28.00	35.00	918.00	12.00
Max	73 853.00	27 295.00	57 270.00	57 88.00	33 6073.00	69 373.00

Source: own calculations.

The highest volatility in terms of price was observed for zinc and copper, in terms of returns for lead and aluminum, and in terms of volume for aluminum and nickel. The distributions of returns and volume are leptokurtic, while they are characterized by different types of asymmetry: returns – left-sided, volume – right-sided asymmetry. The final analysis of risk concerns the relationship between returns and volume. The figure below shows two-dimensional histograms for tin and aluminum.

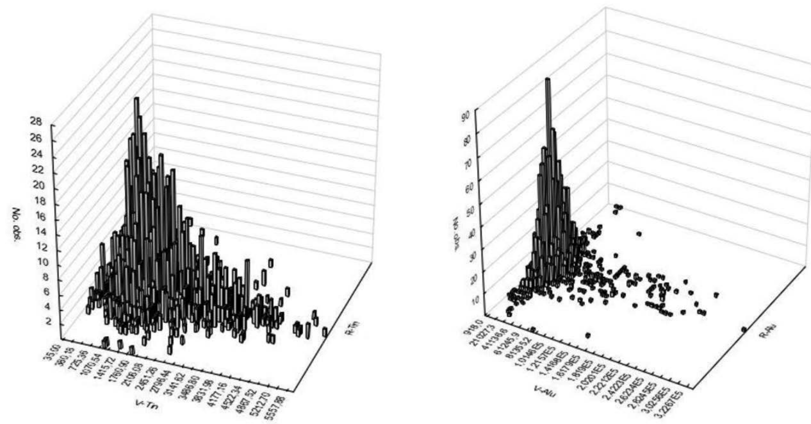

Fig. 2. 2D histograms for tin (left) and aluminum (right): returns (R) vs, volume (V) for the period January 2010 – May 2018

Source: own calculations.

A relationship between returns and the level of turnover for the analysed investments was found. The vast majority of returns concentrate on low volume, regardless of the metal considered. The main emphasis was placed on all three dimensions in the investment risk assessment. The probability of an extreme return

Table 2. Risk measures for returns of base metals for the period January 2010 – May 2018

	Zinc			Lead		
Probability	Consequences	Source		Consequences	Source	
	VaR	Mean	Median	VaR	Mean	Median
0.05	–0.0254	10007.87	8728.00	–0.0262	5128.27	4964.50
0.01	–0.0433	10998.68	8242.50	–0.0456	5009.45	4429.00
0.001	–0.0765	17341.33	20889.00	–0.0786	5135.33	5220.00
Probability	ES	Mean	Median	ES	Mean	Median
0.05	–0.0365	10991.86	8432.00	–0.0388	4997.23	4793.00
0.01	–0.0554	11201.00	8082.00	–0.0608	5299.64	5209.00
0.001	–0.0802	22610.50	22610.50	–0.0826	5220.00	5220.00
Probability	MS	Mean	Median	MS	Mean	Median
0.05	–0.0329	10401.84	8473.00	–0.0341	4818.09	4563.00
0.01	–0.0510	9937.09	7651.00	–0.0571	5299.64	5209.00
0.001	–0.0815	20889.00	20889.00	–0.0840	5220.00	5220.00
Probability	mGlueVaR	Mean	Median	mGlueVaR	Mean	Median
0.05-0.01	–0.0459	10233.81	8300.00	–0.0498	5086.70	4754.00
0.05-0.001	–0.0583	9989.85	7651.00	–0.0717	5180.92	5182.50
0.01-0.001	–0.0678	11708.14	8513.00	–0.0717	5223.89	5209.00

	Nickel			Tin		
Probability	Consequences	Source		Consequences	Source	
	VaR	Mean	Median	VaR	Mean	Median
0.05	–0.0308	7130.28	6689.00	–0.0242	1663.36	1581.50
0.01	–0.0508	5787.36	5454.00	–0.0425	1901.77	1806.00
0.001	–0.0877	5969.33	5973.00	–0.0770	1486.33	1478.00
Probability	ES	Mean	Median	ES	Mean	Median
0.05	–0.0446	6685.72	5876.00	–0.0364	1866.08	1710.00
0.01	–0.0656	6121.75	6386.50	–0.0568	1942.57	1828.00
0.001	–0.1007	4225.00	4225.00	–0.0887	1068.00	1068.00
Probability	MS	Mean	Median	MS	Mean	Median
0.05	–0.0410	6584.75	5973.00	–0.0322	1780.35	1660.00
0.01	–0.0577	5798.27	5876.00	–0.0540	1762.45	1784.00
0.001	–0.1062	4225.00	4225.00	–0.0936	1068.00	1068.00
Probability	mGlueVaR	Mean	Median	mGlueVaR	Mean	Median
0.05-0.01	–0.0551	6487.88	5709.50	–0.0466	1826.07	1660.00
0.05-0.001	–0.0832	6121.75	6386.50	–0.0728	1942.57	1828.00
0.01-0.001	–0.0832	6040.20	5973.00	–0.0728	1889.00	1478.00

	Aluminum			Copper		
Probability	Consequences	Source		Consequences	Source	
	VaR	Mean	Median	VaR	Mean	Median
0.05	–0.0193	31633.4	22214.00	–0.0234	15204.05	12250.00
0.01	–0.0307	24968.35	21331.00	–0.0359	15470.59	12449.50
0.001	–0.0673	21971.67	21628.00	–0.0667	20005.67	15619.00
Probability	ES	Mean	Median	ES	Mean	Median
0.05	–0.0274	25297.56	21181.00	–0.0319	14306.36	12219.00
0.01	–0.0435	35589.17	26047.50	–0.0486	16037.88	13595.50
0.001	–0.0746	22143.5	22143.50	–0.0718	9186.00	9186.00
Probability	MS	Mean	Median	MS	Mean	Median
0.05	–0.0239	26784.35	19732.00	–0.0283	15011.84	12281.00
0.01	–0.0394	30630.91	25336.00	–0.0432	14294.27	12103.00
0.001	–0.0769	18951	18951.00	–0.0735	9186.00	9186.00
Probability	mGlueVaR	Mean	Median	mGlueVaR	Mean	Median
0.05-0.01	–0.0354	24836.46	21479.50	–0.0402	15128.52	12219.00
0.05-0.001	–0.0590	35950	25336.00	–0.0602	16037.88	13595.50
0.01-0.001	–0.0590	35950	25336.00	–0.0602	16037.88	13595.50

Source: own calculations.

was set at the significance level of 0.001, 0.01 and 0.05. The consequence is the level of the return, while the source of risk represents the volume of turnover. The results of the analysis are presented in Table 2.

The results presented for the risk measures calculated on the basis of empirical data indicate that the largest losses, regardless of the level of probability of extremely high losses, were generated by investments in nickel. It was also observed that investments in aluminum and copper were the least risky. On the other hand, the volume of trading was not always proportionally high in terms of corresponding returns. In general, the more extreme the loss, the smaller the average volume (for both mean and median). In the last part of the analysis according to the obtained results, the risk classification was made. The results are shown in Table 3.

This classification is based on the selected risk measure. It is difficult to clearly indicate the relation between all three dimensions. It was observed that usually the lower the probability of a significant loss, the higher the value of this loss in terms of consequences. In the case of VaR, the source of risk, which is the level of volume, is usually high (similarly for modified GlueVaR). In turn, the ES risk measure usually indicates the volume at low level, while MS – at medium level. The results are not very clear, however, a more advanced analysis of risk factors can help in its monitoring and implementation of an appropriate preventive or hedging strategy.

Table 3. Classification of risk on the metals market

Risk measure	Probability	Consequence	Source
VaR	0.05	adverse	high
	0.01	adverse	low
	0.001	catastrophic	high
ES	0.05	adverse	low
	0.01	serious	high
	0.001	catastrophic	low
MS	0.05	adverse	medium
	0.01	serious	medium
	0.001	catastrophic	low
mGlueVaR	0.05-0.01	adverse	low
	0.05-0.001	serious	high
	0.01-0.001	serious	high

Source: own calculations.

5. Conclusion

Risk is a subjective term and is directly related to the individual to which it relates. Despite this, it can be said that regardless of the area of research, in the classical approach risk may be defined by two dimensions: the probability of the occurrence of a risky event and the corresponding consequences. In this paper the authors proposed a new additional dimension – the source of risk, defined by the volume of turnover. The study was based on empirical data from the metals market. The quantitative assessment of risk was based on quantile measures: VaR, ES, MS and modified GlueVaR.

The results of the analysis indicate that high levels of volatility for both price and the return were observed, mainly in the period 2010-2012 and 2017-2018. Both periods are related to the recovery of the global economy from the crisis, hence the upward trends were observed. Moreover, the relationship between return and the level of turnover was detected. Returns from investments in the analysed metals were related to the low level of turnover. The largest losses were observed for investment in nickel, while the smallest – for investments in aluminum. The risk measure and the likelihood of loss were of no importance.

In the context of risk classification, all three dimensions discussed in the theoretical part were used. It was observed that the rarer the probability of an extreme event, the higher the investment loss, but this is not always related to the level of volume. Moreover, the type of risk measure determines the level of consequences and the level of corresponding volume as well. The presented results are an invitation to further research on the nature of the risk observed on the non-ferrous metals market.

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ZARZĄDZANIE RYZYKIEM NA RYNKU METALI

Streszczenie: Celem opracowania jest próba klasyfikacji ryzyka, które można zaobserwować, gdy mamy do czynienia z danymi z rynku metali. Ogólna definicja ryzyka obejmuje dwa wymiary: prawdopodobieństwo wystąpienia zdarzenia ryzykownego i związane z nim konsekwencje zestawu niebezpiecznych scenariuszy. W niniejszym badaniu staramy się dodać nowy wymiar: źródło ryzyka, które można zdefiniować w kategoriach poziomu obrotu (zmienność wolumenu) oraz ceny (zmienność stóp zwrotu). Ryzyko możemy kategoryzować według wielowymiarowego rankingu, na podstawie porównawczej oceny konsekwencji, prawdopodobieństwa i źródła danego ryzyka. Inny wymiar to wybrane miary ryzyka w rozumieniu modelu ryzyka. W analizie ryzyka wykorzystano wybrane miary kwantylowe: VaR, Expected Shortfall, Median Shortfall oraz GlueVaR. W części empirycznej przedstawiamy analizę ryzyka w ujęciu wielowymiarowym przeprowadzoną na rynku metali.

Słowa kluczowe: miara ryzyka, zmodyfikowany GlueVaR, ryzyko ekstremalne, źródła ryzyka, rynek metali.

Quote as: Krężołek, D., Trzpiot, G. (2020). Risk management on the metals market. *Econometrics. Ekonometria. Advances in Applied Data Analysis*, *24*(2).