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THE IMPACT OF CHANGES IN THE BASE AND PRECIOUS METALS PRICES ON CREDIT RISK FACTORS

Summary: The changes in the prices of base and precious metals on the global metal market have a significant impact on credit risk factors. The link between these factors has been neglected over the years by traditional credit risk models. The inclusion of correlation coefficients within the set credit risk model will show the impact of these changes on other variables of credit risk over the years under review and the impact of these changes on the probability of default and the recovery rate. Changes in base metals prices on the London Metal Exchange (LME) for lead and zinc and the London Bullion Metal Association (LBMA) for gold and silver as precious metals were used in the proposed credit risk model for the period of ten years. The research was done by using the multivariate regression analysis model and based on the statistical model evaluation, the significant impact of all observed independent variables on the dependent variable of the proposed model was proved. The construction of the proposed model with proven predictability gives a scientific significance to the research that includes variables of models from different markets, which have a significant impact on the variables from the financial market.

Keywords: base and precious metals, credit risk, default rate, the recovery rate

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1. Introduction

The procyclical economy movement causes fluctuations in all markets that are directly or indirectly affected by these changes. The financial market is most sensitive to cyclical movements where changes occur in the form of negative or positive trends, depending on the recession or expansive state of an economy. Recession movements increase all forms of financial risks, of which the negative change is expressed by the increase of probability and the number of default of corporate clients. Increasing the default of corporate clients leads to the impairment of financial stability at the level of a commercial bank, depending on the number and level of exposure of default clients regarding the bank credit portfolio. These individual adverse changes can also lead to a distortion of global financial security, which can lead to global problems that spill over into other markets.

In this paper, the impact of macroeconomic changes affecting cyclical trends in the economy was researched and, consequently, a correlation between the individual variables related to the price changes of the base and precious metals. Economic history has shown a significant interdependence between the changes of raw material prices expressed through the movement of the base and precious metals prices due to changes in aggregate supply and demand. The assay has set up a model that takes data on price changes of the base and precious metals, the probability of default and recovery rate, the currency changes between the euro and US dollar exchange rate and the rate of the gross domestic product. In the assay a ten-year time series was observed, that is, the years that preceded the latest global financial crisis, and several years after the stabilization period. In this way, a dynamic approach has been introduced in the observation of the problem question, which made it possible to determine movements with an ex-ante and ex-post approach, i.e., movements before and after the financial crisis.

The analysis of the available scientific literature has shown the lack of a large number of scientific articles and researchers that deal adequately with the thematics provided by the proposed model that monitors the movement of set variables in the metal market and the financial market. In this regard, in the first part of this paper, we presented a literature review, which mainly follows certain specific terms related to the topic of this scientific work, on the basis of which we accessed further elaboration and the formation of the proposed research model. Based on the obtained results, a statistical evaluation of the proposed model was made through the application of the multivariate correlation analysis, as well as the assignment of the assessment based on the R test for each of the variables that have an impact on the changes of the default rate. Monitoring the movement of the recovery rate is based on information on the changes in the default rate during the years of the time series and the type of collateral established by a commercial bank. Related with that, a movement in the recovery rate would be observed with the cyclical movement of a given economy.
The proposed model has shown the existence of a significant correlation between the changes of metal prices for lead and zinc on the base metals market and the changes of gold and silver prices on the precious metals market. The significant correlation was confirmed by the obtained high values of the statistical evaluation of the model, which were confirmed by the application of the Pearson coefficient of multivariate correlation regression analysis.

The main goal of this research is to demonstrate the predictive ability of the model’s set variables. With the monitoring of the correlation effects between the set variables, a proposed model showed, with the satisfactory degree of statistical significance, the possibility of projection of future trends on the financial market, notably, in the relation of corporate clients default, and consequently the recovery rate in the case of default. Corporate clients default is particularly important if we look at the impact of the global financial crisis, which, in addition to the financial market crisis, has consequently shown a negative trend in other global markets.

The base research hypothesis of this scientific study is to prove that the negative trend in the changes of the base and precious metals has an impact on negative trends expressed through an increase in the default rate. Consequently, a lower recovery rate in years related to the recessionary economic trends, shown by the fall in the rate of gross domestic products, has a positive correlation with changes of the base and precious metals.

The significance of this research is reflected in the fact that the research has proven a positive correlation between independent variables that show movement in the base and precious metals market in relation to the group of independent variables that describe the movement in the financial market. From this positive correlation between independent variables based on the proposed model, the proposed predictive model’s ability has been proven, which fully justifies the conducted research and provides the possibility of regression extrapolation of the movement of independent variables in a particular future time horizon.

2. Literature review

The global financial and metal markets are closely related, and during the historical changes that have caused certain cyclical developments at the level of the macroeconomic system, a significant correlation between the variables that describe trends in these markets has been noted. As one of the primary variables in assessing the credit risk on the financial market that affects the stability of the financial system is the probability of default. The European Banking Authority1

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1 European Banking Authority (2016): Final Report – Guidelines on the application of the definition of default under Article 178 of Regulation (EU) No. 575/2013, EBA/GL/2016/07, 1-107
(EBA) defines the default as temporary or permanent incompetence of the borrower in servicing its financial obligations. It is mostly determined depending on the number of days of delay in the credit obligations payment. The delay in credit obligation payment is set at intervals of 30 to 90 days. A delay that is over 90 days presupposes permanent or temporary irregularity of the debtor in servicing the financial obligations, or the debtor’s default. The 90-day delay is used for accounting purposes and it is defined in the International Accounting Standard 9 (IFRS 9). Default leads to non-performing loans\(^2\) (NPL) that directly threaten the financial stability of a macroeconomic system.

In the case of the default, it is essential to determine the rate of recovery \(rr\), i.e., the degree of collection of financial liabilities by a commercial bank. Bessis\(^3\) presented the rate of recovery as a multiplication of the credit exposure and the percentage of losses resulting from the default (Loss Given Default - LGD). Misankova\(^4\) defined the rate of recovery as a value that remains to the creditor after the debtor’s debt, determined as a relative value, depending on the height of the losses resulting from the default.

On the other hand, the authors Altman, Brady, Resti and Sironi\(^5\) introduced the recovery rate through three models. In the first model, the probability of the default and recovery rates are in the function of the structural characteristics of the corporate debtor. In the second model, the recovery rate is an exogenous variable, which is independent of the value of the firm and is defined as the fixed ratio of unpaid debt, while in the third model the assumption is made of the dynamic movement of the probability variables of the default and the recovery rate. Ciby\(^6\) defined the recovery rate as the residual value after the case of default (Value Given Default - VGD).

The influence on certain cyclical movements is conditioned by the higher number of exogenous variables, which cause the expansive or recession movement of an economy. This economy movement could be seen through the dependence that is conditioned by the movement of macroeconomic variables, the sensitivity of the economic system to these external factors, and the movement of raw material and base metals prices that directly condition the state of one economy. The state of the economy, which is defined through parameters of aggregate supply

\(^2\) European Banking Authority (2014): EBA Final draft Implementing Technical Standards – On Supervisory reporting on forbearance and non-performing exposures under article 99(4) of Regulation (EU) No. 575/2013, EBA/ITS/2013/03/rev1, 1-65

\(^3\) Bessis, J. (2002): Risk Management in Banking, John Wiley & Sons, New York, 439

\(^4\) Misankova, M. (2015): Determination of Default Probability by Loss Given Default, Procedia Economics and Finance, No. 26, 411-417

\(^5\) Altman, E. I., Brady, B., Resti, A., Sironi, A. (2005): The Link between Default and Recovery Rates: Theory, Empirical Evidence, and Implications, The Journal of Business, Vol 78, No. 6, 1-27

\(^6\) Ciby, J. (2013): Advanced Credit Risk Analysis and Management, John Wiley and Sons, United Kingdom, 270
and demand, has a significant impact on the stability and movement of individual financial markets. The stability of individual financial market also depends on the depth of the financial market that is conditioned by the structure of corporate clients, the extent and the place of their business. It is also conditioned by the fact whether these corporate clients have dominant domicile business participation or whether they are present in the international financial market, and consequently have an impact or are sensitive to certain trends in the global financial market.

On the other hand, there is the influence of the movement of precious metals prices shown on the LBMA market, which is determined in relation to the recessionary and expansive trends in the global financial market. Price movements of these metals often do not have a direct correlation concerning the movement of the base metal prices. Prices of precious metals most often represent the „escape“ to safe security, such as gold or silver, in case of recession and negative trends in the global financial market. Gold has recorded the highest average values on the precious metal market after nearly three decades. Gold prices on the international precious metals market over the years following the global financial crisis have recorded a value that is 200% above the long-term average. Gold held relatively stable values during the „golden period“ which were valid for the duration of the Bretton Woods standard.

The financial crisis that began in mid-2007 led to a general decline in lending activity in the global financial market, which was 47% lower in the last quarter of 2008 compared to the same period in 2006 and 79% lower than the peak of the credit crunch from the second quarter of 2007, according to Ivashin and Scharfstein. This scientific paper presents the impact of the financial crisis that has led to a decline in economic activity, and consequently to an increase in the rate of corporate clients default. One of the most common terminological terms given by Baldwin describing the global financial crisis, which led to the global recession, is that it is sudden, difficult and synchronized. Fluctuation in the growth rate of the gross domestic product is significantly lower than the decline in aggregate demand. As a confirmation of this correlation, Freund describes

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7 Credit Suisse (2011): Long Run Commodity Prices: Where Do We Stand?, Fixed Income Research, 7
8 The Bretton Woods agreement was introduced on July 22, 1944, and represents an international financial agreement that introduces a gold standard that was linked to national currencies. This agreement confirms the introduction of the US dollar as a world currency, which had a gold cover, while other currencies were fixed to the US dollar. The Bretton Woods agreement, and therefore the golden currency validity, was abolished in 1973.
9 Ivashina, V., Scharfstein, D. (2009): Bank lending during the financial crisis of 2008, Journal of Financial Economics 97, 1-45
10 Baldwin, R. (2009): The great trade collapse: What caused it and what does it mean?, Economics, Graduate Institute, Geneva, 1-12
11 Freund, C. (2009): Demistifying the collapse in trade, World Bank Integration and Investment Department, 1-3

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that the decline in global demand for commodities (base metals) is up to 5 times higher than the global decline in gross domestic product. The impact of the crisis on the financial market correlated with other markets such as the metal market, which also experienced a fall in the volume of aggregate demand, leading to an adverse movement in base metal prices. On the other hand, the recession movement caused a significant rise in the price of precious metals.

Delle Chiaie, Ferrara and Giannone\textsuperscript{12} assumed that the price fluctuation in the global commodity market was conditioned by the influence of global factors, which these authors associate with cyclical trends in the economy, and which were caused by a recession period. The authors observed the movement of exporting activities of leading companies in the Brazilian market. In a conducted analysis, they found that Brazilian companies confronted with specific "brakes" of growth and development, which were most often reflected in costs of borrowing, currency risk and access to capital. Brazilian companies, which were predominantly related to the export of goods, had an average cost of financing over 32% annually and recorded lower percentages of profit margins due to a weak domestic currency relative to the US dollar, even in years that have carved a price increase of base metals. It has been shown that currency risk has vital importance in the proposed model, which measures the probability of default.

In order to include the cyclical movement at the global level, the proposed model included the movement of base metal prices within the 10-year time series, the period preceding the financial crisis in 2008, and years of stabilization of operations after the global financial crisis. In the last few years, there has been a stabilization of operations in global markets, which has been presented by the growth of the Credit Suisse Commodities Benchmark Index (CSCBI\textsuperscript{13}), which has risen by 80% compared to the beginning of 2009. Credit Suisse analysts note that base metal prices, and the fluctuation of lead and zinc prices, have recorded the highest value for the last few decades. Observing the changes in the prices of lead and zinc is significant because these metals are obtained from the same ore body. Therefore, it is easier to observe the relationship that influences the global fluctuation of the prices of these base metals because their production most commonly comes from mines that produce ore lead and zinc. Accordingly, it is possible to determine the trend in the movement of the production volume of these mines, which is conditioned by the aggregate demand on the metal market. Lead price changes recorded a 45% increase over the 110-years annual average lead price, while zinc change was 15% above the average.\textsuperscript{14} In the research of these analysts, it is pointed out that the currency effect was significant, especially

\textsuperscript{12} Delle Chiaire, S., Ferrara, L., Giannone, D. (2017): Common Factors of Commodity Prices, Working paper, Banque de France, 1-40

\textsuperscript{13} Credit Suisse (2011): Long Run Commodity Prices: Where Do We Stand?, Fixed Income Research, 1

\textsuperscript{14} Ibid., 5
regarding the currency exchange rate against other currencies, which significantly rose in value against the US dollar, such as the euro and the Japanese yen. Also, an essential factor, which predetermines the movement of metal prices, is the impact of demand on the Chinese market, which should keep the price of base metals at a high level.

The proposed model predicts a cross-sectional analysis of global factors that affect the default and in the case of default they affect the recovery rate. The model analyzes primary macroeconomic factors that show cyclical trends in the economy, such as the movement of gross domestic product, for the world’s largest economies, such as the synthetic value of gross domestic product growth rates for EU countries, the US and China markets. This approach in the analysis has examined the movement in the global market. The analysis found that there are some significant differences in the rate of movement in different markets. As a synthetic value that is unique to all global markets, the proposed model used the values of base metal price movements based on reports on average monthly trading prices on the London Metal Exchange Market for base metals, as well as the average monthly trading prices for precious metals obtained from the LBMA market.

The analysis showed that there is a relationship between the state of the economic cycle, which affects the emergence and increase of the rate of default on the global financial market, as well as the fall in the value of the recovery rate in recessionary periods. The importance of the analysis was to prove the multivariate correlation between the movement of basic metals prices, precious metals, the movement of gross domestic product. The aim was also to prove the currency fluctuation between the euro and the US dollar (since all international trading activities on the metal market are shown and realized in this currency pair), and dependent variables of the corporate debtor’s rate of default and recovery rate. Two dependent variable rates of default and recovery rate have a mutual correlation value, and it is in most cases determined by the type and degree of collateralization between a commercial bank and a corporate debtor. However, there is also a direct correlation in the movement of these two rates, which is related to cyclical trends in the economy.

3. Proposed model setting

The proposed model sets the variables, on the basis of which correlation coefficients have been identified. They describe the causal consequence of default and consequently, the recovery rate in a particular financial market. The analysis of the set variables was made using the multivariate correlation analysis by calculating the Person’s correlation coefficient with the calculation of the R test, R² test and corrected R² test. The function of calculating Pearson’s correlation coefficient could be represented as follows:
The Pearson correlation coefficient is called the R test in the literature, and the application of R² and the corrected R² test is used in situations, when there are more variables which are used within the multivariate regression function, in order to obtain a more reliable model estimation based on the corrected R² test. In the research based on the Person R test, it was noted that when increasing the number of variables that participate in the correlation assessment, the result of the R test could increase which would give unreliable numbers. For this reason, the values of R² and the corrected R² test were used in the statistical evaluation of the results by the proposed model. The proposed model predicts that several independent variables are affected by the dependent variable of the default rate, and for this reason, the proposed model used multivariate regression analysis. The regression curve, which has extrapolation function of independent variables, can be shown as:

\[ f(y) = \beta_0 + \beta_1 x_1 + \ldots + \beta_p x_p \]

The proposed model used the variables of base metal price movements on the LME market, the variables PbP for the movement of the prices of lead and ZnP for the movement of the price of zinc. In addition to these variables, the model observed the movement of precious metals prices on the LBMA market, using the variable AuP for the movement of gold prices and AgP for the movement of silver prices. In order to obtain as precise values as possible of the variables taken in the correlation analysis, each of the mentioned variables has been modified by calculating the index according to the rank at a price level over a time series of 10 years. From the ranged values of the prices of base and precious metals, indices of 0-1 were assigned. These values were multiplied by the percentage value of default for the years of the time series. In 2009, the highest value of the global corporate rate of default was recorded at 4.18%\(^{15}\), so that in this year, the index value of 1.00 was assigned to all independent variables. As the year 2009 was taken as the base year, the year in which the rate of default was the highest, for the other years of the time series, the relative value of the default was determined, depending on this base year. Relative values of the default rate per year were multiplied

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\(^{15}\) S&P Global Ratings (2017): 2016 Annual Global Corporate Default Study And Rating Transitions, 5

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by the value of the index of independent variables of the price of metals per year. Based on this, new independent variables have been formed and they measure the correlation of the related change in the price of base and precious metals at the default rate. The modified index value of these variables have been obtained:

\[ f_{\text{LME}_{\text{cor}}} = [\text{PbDPI}, \text{ZnDPI}] \]
\[ f_{\text{LBMA}_{\text{cor}}} = [\text{AuDPI}, \text{AgDPI}] \]

where \( f_{\text{LME}_{\text{cor}}} \) is a correlation function of independent variables, which measure the impact of the change in metal prices on the LME market and \( f_{\text{LBMA}_{\text{cor}}} \) the correlation function of independent variables, which measure the impact of changes in the LBMA market.

As a macroeconomic variable in the proposed model, the gross domestic product (GDP)\(^{16}\) variable was used for the economies of the European Union, the US economy and China. Based on the value of the growth rate of gross domestic product for the three observed markets, there is a significant difference in the fluctuation of the GDP growth rate. While the growth rates in gross domestic product for the markets of the European Union and the US had similar fluctuation trends, the rates recorded on the Chinese market had double-digit growth, and in the recession years, they had significantly higher rates of decline. Due to the unequal trend in the growth rate of gross domestic product in different markets, a modified Gross Domestic Product Index (GDPI) formed, which is related to the recorded default rates\(^{17}\) in the observed time series. Based on the default rates for all years, the observed time series GDPI variable has assigned values ranging from 0-1. The Helwege and Kleiman\(^{18}\), observing the differences in GDP growth rates in different markets, found that rates fluctuating between 5-6% could have the same likelihood of default as, for example, a fall of 1-2% in some other less developed markets. A function that measures the interdependence of the independent macroeconomic variable and the dependent variable of the default rate could be represented as follows:

\[ f_{\text{GDPI}_{\text{cor}}} = \left[ \text{GDPI}_{\text{EU}}, \text{GDPI}_{\text{US}}, \text{GDPI}_{\text{CH}} \right] \]

In addition to these primary variables and macroeconomic index, a variable describing the value changes of the currency pair (FX)\(^{19}\) between the euro and the

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\(^{16}\) Word Bank Data – https://data.worldbank.org/indicator/

\(^{17}\) S&P Global Ratings (2017):2016 Annual Global Corporate Default Study And Rating Transitions,1-191

\(^{18}\) Helwege, J., Kleiman, P. (1996): Understanding Aggregate Degault Rates of High Yield Bonds, Current Issues in Economics and Finance, Vol. 2, No. 6, Federal Reserve Bank of New York, 1-6

\(^{19}\) OFX – https://www.ofx.com
US dollar for all years of the time series were used in the analysis made by the proposed model. This currency pair was used because all values and transactions on the commodity markets are expressed in this currency pair. In order to reflect more accurately the value changes of an independent variable that represent the movement of the currency pair, the modified values of the currency index have been assigned to form a new independent variable (FXI). This currency pair movement has been done because the changes between these two currency pairs over the years had small percentage changes. In order to show the depreciation and appreciation of the US dollar against the euro, a value between 0-1 was assigned for every year of time series.

The independent variable FXI was used to prove the correlation between the price of basic metals, lead and zinc on the LME market, and the price of gold and silver on the LBMA market, and depending on the currency value changes of the US dollar. In the years when the US dollar is appreciating against the euro, we have lower prices for base metals and vice versa. Observing the movement of precious metals prices, we have almost the same trend of movement as in the case of the change of base metal prices. Valle, Toneto, Cicogna and Tarintin, in their research of export-oriented companies in the Brazilian market, show a negative interdependence in the case of depreciation of the domicile currency against the US dollar and the negative correlations between currency relations and the change of commodity prices on the global market. The function of the interdependence of the influence of the independent variable of the change in the currency relation on the dependent variable of the change of the prices of base metals could be shown as follows:

\[
f_{(FX_{cor})} = [PbP, ZnP, AuP, AgP]
\]

All previously defined functions define all independent model variables that participate in estimates of correlation interdependence to the dependent variable in the proposed model, which is defined as the default rate.

On the basis of the setting of all independent variables of the proposed model, a research assumption was made that independent variables from the base and precious metals market have a significant positive correlation effect on independent financial market variables expressed through independent variables of the default rate and recovery rate. Also, it was assumed that there is a significant correlation effect of other independent variables related to macroeconomic trends in gross domestic product from different global markets to the changes of independent variables of metals prices on the metal market. The proposed model also assumed that there is a positive correlation between the value changes of the currency pair between the US dollar and the euro.

Valle, M. R., Toneto, R., Vierira, M. P., Tarantin, W. (2017): The Correlation Effect between Commodity Prices and Exchange Rate for Brazilian Firms’ Balance Sheets, Inter-American Development Bank, Department of Research and Chief Economist, VI Series, IDB-TN-1168, 1-61
### Table 1. Independent model variables values

|            | LMBA Au |            | LMBA Ag |            | LME Pb |            | LME Zn |            |
|------------|---------|------------|---------|------------|--------|------------|--------|------------|
|            | Avg. per year | range | AuDPI | Avg. per year | range | AgDPI | Avg. per year | range | PbDPI | Avg. per year | range | ZnDPI |
| 2005       | 444,89  | 11        | 0,01   | 7,31121    | 11     | 0,01 | 976,45     | 11     | 0,01 | 1.381,85     | 11     | 0,01 |
| 2006       | 604,52  | 10        | 0,01   | 11,57247   | 10     | 0,01 | 1.289,72   | 10     | 0,01 | 3.275,29     | 1        | 0,01 |
| 2007       | 696,76  | 9         | 0,02   | 13,39490   | 9       | 0,02 | 2.577,40   | 1       | 0,02 | 3.241,38     | 2        | 0,02 |
| 2008       | 872,12  | 8         | 0,13   | 15,02006   | 7       | 0,39 | 1.997,62   | 7       | 0,34 | 2.084,40     | 6        | 0,26 |
| 2009       | 972,98  | 7         | 1,00   | 14,65399   | 8       | 1,00 | 1.719,27   | 9       | 1,00 | 1.655,11     | 10       | 1,00 |
| 2010       | 1,225,06 | 5       | 0,23   | 20,15745   | 4       | 0,17 | 2.148,45   | 3       | 0,12 | 2.160,74     | 5        | 0,15 |
| 2011       | 1,573,25 | 2       | 0,10   | 35,11192   | 1       | 0,06 | 2.401,83   | 2       | 0,06 | 2.193,34     | 3        | 0,06 |
| 2012       | 1,668,55 | 1       | 0,11   | 31,14904   | 2       | 0,11 | 2.062,34   | 6       | 0,19 | 1.948,06     | 7        | 0,19 |
| 2013       | 1,410,92 | 3       | 0,15   | 23,82958   | 3       | 0,13 | 2.142,26   | 4       | 0,13 | 1.910,34     | 9        | 0,23 |
| 2014       | 1,266,27 | 4       | 0,12   | 19,07833   | 5       | 0,12 | 2.095,68   | 5       | 0,10 | 2.162,00     | 4        | 0,07 |
| 2015       | 1,160,35 | 6       | 0,30   | 15,69783   | 6       | 0,26 | 1.786,50   | 8       | 0,30 | 1.932,51     | 8        | 0,26 |

|            | % GDP     | EU | GDP_EU | US | GDP_US | CH | GDP_CH | FX | EUR/USD | Default rates |
|------------|-----------|----|--------|----|--------|----|--------|----|---------|---------------|
| 2005       | 2,109     | 0,04 | 3,345  | 0,01 | 11,396 | 0,03 | 1,24638 | 0,60 | DR | 0,14 |
| 2006       | 3,348     | 0,01 | 2,667  | 0,02 | 12,719 | 0,01 | 1,25632 | 0,48 | DR | 0,11 |
| 2007       | 3,079     | 0,01 | 1,779  | 0,05 | 14,231 | 0,00 | 1,37041 | 0,37 | DR | 0,09 |
| 2008       | 0,484     | 0,30 | -0,292 | 0,39 | 9,654  | 0,17 | 1,47137 | 1,80 | DR | 0,43 |
| 2009       | -4,349    | 1,00 | -2,776 | 1,00 | 9,400  | 1,00 | 1,39448 | 4,18 | DR | 1,00 |
| 2010       | 2,101     | 0,12 | 2,532  | 0,12 | 10,636 | 0,09 | 1,32739 | 1,20 | DR | 0,29 |
| 2011       | 1,706     | 0,11 | 1,601  | 0,15 | 9,536  | 0,10 | 1,39271 | 0,80 | DR | 0,19 |
| 2012       | -0,425    | 0,24 | 2,224  | 0,14 | 7,856  | 0,16 | 1,25870 | 1,14 | DR | 0,27 |
| 2013       | 0,258     | 0,20 | 1,677  | 0,18 | 7,758  | 0,18 | 1,32846 | 1,06 | DR | 0,25 |
| 2014       | 1,743     | 0,09 | 2,569  | 0,05 | 7,298  | 0,14 | 1,32917 | 0,69 | DR | 0,17 |
| 2015       | 2,316     | 0,07 | 2,862  | 0,03 | 6,900  | 0,30 | 1,10983 | 1,36 | DR | 0,33 |

Source: Author’s research
3.1. Statistical model evaluation

On the basis of all independent model variables, the analysis was made on the influence of individual independent variables on the default rate as the dependent variable. A statistical evaluation of the model was done with the help of the multivariate correlation regression analysis. With this statistical evaluation of the model, it was possible to measure the impact of the first group of independent variables, which are related to changes in prices on the LME market and their impact on the movement of the default rate. The values of the $R^2$ test of 0.981 and the corrected $R^2$ test of 0.977 represents a significant value that confirms the significant correlation of prices on the LME market and the default rate. Observing the correlation matrix between the independent and dependent model variables given in Table 2, shows a significant correlation between the independent variables of the proposed model and the dependent variable.

**Table 2. Correlation matrix between independent variables from the LME market which describe the changes of base metal prices and the default rate**

|       | DR  | AuDPI | AgDPI |
|-------|-----|-------|-------|
| DR    | 1.000 | 0.967 | 0.990 |
| AuDPI | 0.967 | 1.000 | 0.954 |
| AgDPI | 0.990 | 0.954 | 1.000 |

**Source:** Author’s research

As the statistical significance of independent variables from the LME market for the dependent variable of the changes of the default rate was confirmed, the coefficients, by which it was possible to construct the multivariate regression function, were calculated. These coefficients are given in Table 3.

**Table 3. Coefficients of multivariate regression function for independent variables from the LME market**

|       | Non-standardized coefficients | Standardized coefficient |
|-------|-----------------------------|--------------------------|
|       | B                           | Stand. Deviation         | Beta         |
| Constant | 0.412                      | 0.063                    |              |
| AuDPI   | 1.085                       | 0.631                    | 0.247        |
| AgDPI   | 3.247                       | 0.617                    | 0.755        |

**Source:** Author’s research

It was possible to construct a multivariate regression function, taking the obtained coefficients from Table 3, which gave the model the predictability, i.e., the possibility of projection of the changes of the default rate in the future time horizon with the changes of base metal prices from the LME market. Multi-
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A multivariate regression function, depending on independent variables from the LME market, can be represented as:

$$\gamma_{LME} = 0.412 + 1.085x_1 + 3.247x_2$$

An additional assessment of the model included the analysis based on independent variables, which measure the impact of the change in the price of precious metals on the LBMA market. Table 4 gives correlation coefficients within the correlation matrix showing the correlation between two independent variables and one dependent model variable. Based on the results, it could be seen that the independent variable ZnDPI has a high statistical significance. Using the Pearson coefficient of multivariate correlation given through the evaluation of the R-test model, the values of $R^2$ and the corrected $R^2$ test were obtained from 0.985 and 0.982, respectively. Table 5 shows the correlation coefficients from which it was possible to construct a multivariate regression function. The structure of the multivariate regression function is the prediction of the model based on the independent variables of the change in the price of precious metals on the LBMA market.

### Table 4. Correlation matrix between independent variables from the LBMA market that describes the changes of precious metals prices and the default rate

|        | DR  | PbDPI | ZnDPI |
|--------|-----|-------|-------|
| DR     | 1.000 | 0.052 | 0.990 |
| PbDPI  | 0.052 | 1.000 | 0.013 |
| ZnDPI  | 0.990 | 0.013 | 1.000 |

Source: Author’s research

### Table 5. Coefficients of multivariate regression function for independent variables from the LBMA market

|        | Non-standardized coefficients | Standardized coefficient |
|--------|------------------------------|--------------------------|
|        | B                            | Stand. deviation         | Beta         |
| Constant | 0.390                     | 0.075                    |              |
| PbDPI   | 0.014                      | 0.017                    | 0.039        |
| ZnDPI   | 4.342                      | 0.212                    | 0.989        |

Source: Author’s research

Multivariate regression function based on changes in precious metals prices on the LBMA market could be shown as follows:

$$\gamma_{LBMA} = 0.390 + 0.014x_1 + 4.342x_2$$
The latest evaluation of the model provides an evaluation of the impact of changes in the growth rates of gross domestic product in the three most important global markets, the markets of the European Union, the United States and China. From the historical movement of all macroeconomic indicators that measure the degree of industrial growth and development and the impact on aggregate supply and demand, it has been proven that these three markets are the most important for global movements. When applying the results of these variables to some other less developed markets, it is necessary to construct a modified coefficient. It has been shown that changes in percentages even among these most developed global markets are not the same and that a change of 5-6% of the Chinese market could be compared with a change of 1.5-2% in the other two markets. The difference is even more significant if we consider the changes in the gross domestic product in less or insufficiently developed markets. When analyzing these markets, a coefficient that has a correlation value that is consistent with the correlation values of fluctuations in the more globally developed markets should be applied.

The statistical evaluation of the model for these independent variables obtained the values of the $R^2$ test of 0.982 and the corrected $R^2$ test of 0.974. Results from the $R$ test also have significant values, which have demonstrated the positive correlation impact of all independent variables on the dependent variable of the model. Table 6 shows the migration matrix of correlation values between independent and dependent model variables.

**Table 6. Correlation matrix between independent variables describing the fluctuations in the growth rate of gross domestic product and the default rate**

|          | DR   | GDPI\(_{EU}\) | GDPI\(_{US}\) | GDPI\(_{CH}\) |
|----------|------|---------------|---------------|---------------|
| DR       | 1,000| 0,978         | 0,967         | 0,972         |
| GDPI\(_{EU}\) | 0,978| 1,000         | 0,984         | 0,949         |
| GDPI\(_{US}\) | 0,967| 0,984         | 1,000         | 0,916         |
| GDPI\(_{CH}\) | 0,972| 0,949         | 0,916         | 1,000         |

*Source: Author’s research*

**Table 7. Coefficients of multivariate regression function for independent variables of fluctuations in the rate of growth of gross domestic product**

|          | Non-standardized coefficients | Standardized coefficient |
|----------|------------------------------|-------------------------|
|          | B                            | Stand. deviation        | Beta        |
| Constant | 0,434                        | 0,075                   |             |
| GDPI\(_{EU}\) | 0,085                    | 1,707                   | 0,019       |
| GDPI\(_{US}\) | 1,986                    | 1,310                   | 0,464       |
| GDPI\(_{CH}\) | 2,335                     | 0,752                   | 0,529       |

*Source: Author’s research*
Based on the correlation coefficients from Table 7, a multivariate regression function can be constructed based on the fluctuation of the growth rate of gross domestic product in the three largest global markets, such as:

$$y_{GDP} = 0.434 + 0.085x_1 + 1.986x_2 + 2.335x_3$$

The construction of three regression functions ($y_{LME}$, $y_{LBMA}$, and $y_{GDP}$) demonstrated the predictability of the set model. Also, the model approved a significant correlation impact of the independent model variables on the dependent variable of the changes of corporate client default rates. The statistical evaluation of the model based on the application of the R test showed the positive influence of all tested independent model variables on the movement of the default rate in the observed time series of ten years.

### 3.2. Correlation ratio between the recovery and the default rate

The proposed model has shown a strong correlation between the fluctuation of prices of base and precious metals and the appearance of the default rate, which is caused mainly by cyclical trends in the economy and macroeconomic changes. It could be concluded that there is also a significant degree of correlation between the movement in the level of the loss regarding default and the relative value of commercial banks’ collections in the case of corporate clients default, observing the recovery rate. Based on the data in Table 8, it could be seen that the percentage of recovery rates in the case of corporate loans with first-class security by one commercial bank had discounted values in the range of 15-20% during expansive years, while the percentage in recession years was between 40-50%. The first value is a value that in the case of a default covers the LTV ratios value. This value is taken when setting up collateral and it guarantees the collection of the commercial bank, while in the recession years a significant fall in the value of the recovery rate was shown, which caused losses at a global level that were over 20%.

It could be seen that this rate had a downward trend in poorly rated clients and that in recession years this percentage of losses at the level of one rating category had values that exceeded 15%, looking at the percentage of credit losses in rating categories of corporate clients. These values of credit losses for corporate clients and rating categories, as well as the recovery rate, have a significant positive correlation with the changes in the default rate. The correlation coefficient between the recovery rate and the default rate was evaluated by Pearson R test and it has a value of 0.708, which represents a significant statistical correlation value. The change in the recovery rate as an independent variable of the model was observed only in relation to the dependent variable of the default rate, and not in relation to
other independent variables of the model, which were measured by the correlation between the changes in the price of base and precious metals and the default rate. The movement of the change in the prices of base and precious metals, as well as the movement of the growth rate of gross domestic product and currency changes, has a direct impact on the fluctuations of the default rate.

Table 8. Recovery rate and the corporate clients’ default rate changes for the time series 2005-2015

| Year | Recovery rate (RR) | Default rate (DR) | Aaa | Aa | A | Baa | Ba | B | Caa-C | All rating categories |
|------|-------------------|-------------------|-----|----|---|-----|----|---|-------|----------------------|
| 2005 | 83,8%             | 0,60              | 0,0%| 0,0%| 0,0%| 0,1%| 0,0%| 0,4%| 3,3%  | 3,8%                  |
| 2006 | 83,6%             | 0,48              | 0,0%| 0,0%| 0,0%| 0,0%| 0,1%| 0,5%| 2,7%  | 3,3%                  |
| 2007 | 68,6%             | 0,37              | 0,0%| 0,0%| 0,0%| 0,0%| 0,0%| 0,0%| 2,3%  | 2,3%                  |
| 2008 | 61,7%             | 1,80              | 0,0%| 0,3%| 0,3%| 0,7%| 1,6%| 2,7%| 7,1%  | 12,7%                 |
| 2009 | 53,6%             | 4,18              | 0,0%| 0,0%| 0,2%| 0,6%| 1,1%| 4,6%| 16,5% | 23,0%                 |
| 2010 | 70,9%             | 1,20              | 0,0%| 0,0%| 0,1%| 0,0%| 0,0%| 0,2%| 4,2%  | 4,5%                  |
| 2011 | 70,9%             | 0,80              | 0,0%| 0,1%| 0,0%| 0,2%| 0,1%| 0,2%| 3,4%  | 3,9%                  |
| 2012 | 66,4%             | 1,14              | 0,0%| 0,0%| 0,0%| 0,0%| 0,1%| 0,3%| 4,4%  | 4,8%                  |
| 2013 | 76,2%             | 1,06              | 0,0%| 0,0%| 0,0%| 0,1%| 0,3%| 0,5%| 3,4%  | 4,3%                  |
| 2014 | 78,4%             | 0,69              | 0,0%| 0,0%| 0,0%| 0,0%| 0,1%| 0,3%| 2,5%  | 2,9%                  |
| 2015 | 64,1%             | 1,36              | 0,0%| 0,0%| 0,0%| 0,0%| 0,2%| 1,4%| 4,3%  | 5,9%                  |

Source: Moody’s Investors Service

Chart 1. Corporate default and recovery rates changes in the period 1983-2015

Source: Moody’s Investors Service

Van Vuuren, G., De Jongh, R., Verster, T. (2017): The Impact of PD-LGD Correlation on Expected Loss and Economic Capital, International Business and Economic Research Journal, Vol. 16, No. 3, 158.
On the other hand, the changes in the recovery rate are in direct correlation with the changes in the default rate. The relative values of the recovery rate depend on the level of the default and the cyclical movements in the economy that determines the ability to realize and collect the receivables of a commercial bank in case of corporate default. In addition to measuring the correlation between the default rate and the recovery rate for a commercial bank, it is important that, based on the changes of loss given default values, it can adequately construct a migration matrix based on its cohort of corporate clients. In this way, a commercial bank can further enhance the predictive ability of the model by being able to calculate the level of credit risk through the migration movements of corporate clients of a homogeneous cohort or from the entire credit portfolio. Based on this information, a commercial bank may be prepared to respond to cyclical economic trends adequately. The commercial bank responds on time, based on its credit portfolio, and reduces the level of required economic capital, by applying measures related to the establishment of additional collateral from credit exposure and the measure of collecting receivables from clients, who have specific problems regarding their business.

4. Concluding remarks

The analysis based on the proposed model has proved the significance of the correlation of independent variables, which measure the correlation impact of the changes in the price of base and precious metals at the default rate. The proposed model has proven the significant impact of independent macroeconomic variables that were given through the growth of gross domestic product growth rate, as well as independent variables that measure currency risks, which is expressed through the changes of the currency pair of the euro and the US dollar. On the basis of the obtained high values of the statistical evaluation of the model, it be could proven that there is a strong correlation between the changes of base metals prices caused by changes at the level of aggregate supply and demand in the global commodity market. These results proved the base hypothesis. The research showed that in the recession years, the observed time series decreased the price of base metals and that in those years there was also an increase in the rate of corporate clients default. Consequently, during the recession years, the growth rate of gross domestic product decreased and there came to the correction of the euro/US dollar exchange rate. The recession period led to an increased percentage of credit losses caused by adverse changes in the recovery rate.

In this regard, the cause-effect relationship between the default rate and the recovery rate, which was significantly overwhelming in the years that marked the economic crisis from the beginning of 2007-2009, has been proven. In those years, the analysis of official data revealed that commercial banks had the high-
The analysis showed that there is a correlation relationship of the movement of precious metals prices, especially gold and silver, but that it has a reversed proportional trend of changes relative to the movement of base metal prices. Precious metals prices also recorded, as well as base metals prices, their historical trading value, and the rise in gold prices was also presented as the ratio of the impact of certain macroeconomic trends caused by the abandonment of golden value, and the impact of the US dollar on the movement of the base and precious metals prices. We can present the changes in US dollar prices as a correlation of the value depending on the changes in base metals prices. In cyclical movements that caused the recession economy, the prices of base metals had lower values, and in those years the US dollar had an appreciation in value against other currencies, and vice versa in the expansive years of the economic cycle. Based on the results we proved the significant influence of the changes in the price of the base and precious metals on the changes of the rate of default and the recovery rate, giving a commercial bank the possibility to construct multivariate regression functions by the proposed model independent variables. With this predictability, banks can extrapolate the default rates with a statistical significance of the analyzed proposed model independent variables.
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KORELACIONI EFEKAT UTICAJA PROMENE CENA BAZNIH I PLEMENITIH METALA NA FAKTORE KREDITNOG RIZIKA

Sažetak: Promene u cenama baznih i plemenitih metala na globalnom tržištu metala i njihov uticaj na faktore kreditnog rizika imaju signifikatni uticaj. Veza između ovih faktora bila je zanemarena tokom godina od strane tradicionalnih modela kreditnog rizika. Uključivanje korelacionih koeficijenata u okviru postavljenog modela kreditnog rizika pokazaće jačinu uticaja ovih promena na ostale varijable kreditnog rizika tokom posmatranih godina i uticaj ovih promena na verovatnoću disolta i stopu oporavka. U posmatranom modelu kreditnog rizika uzete su promene cena baznih metala sa Londonske berze metala (London Metal Exchange - LME) za olovo i cink i Londonskog udruženja plemenitih metala (London Bullion Metal Association - LBMA) za zlato i srebro kao plemenitih metala za period od 10 godina. Istraživanje je sprovedeno primenom modela multivarijacine regresione analize, a na bazi statističke ocene modela potvrđen je signifikatni uticaj svih posmatranih nezavisnih varijabli na zavisnu varijablu modela. Konstrukcijom predloženog modela koji ima dokazanu prediktibilnost dat je naučni značaj istraživanju koje uključuje varijable modela koje su različitih tržišta, ali koje imaju signifikatni uticaj na varijable sa finansijskog tržišta.

Ključne reči: bazni i plemenit metali, kreditni rizik, stopa disolta, stopa oporavka