The Influence of Economic Factors on World Copper Production

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http://doi.org/10.29227/IM-2022-01-06

Submission date: 01-02-2022 | Review date: 28-03-2022

Abstract

Copper is a very important mineral that has a wide application in industry, especially in the electrical industry and energy industry. With the increase in electromobility, its potential will grow in the future. Any shortage of copper on the world market could thus endanger modern industry. Therefore, the authors decided to deal with the influence of economic factors (price, population, GDP and cumulative inflation) on copper production and with creation of suitable econometric models that best expressing the relationship between production and economic factors for the period 2010-2019 in their article. The influence of economic factors on world copper production is examined using the Pearson correlation coefficient. It was found that copper production is inversely proportional to the price of copper, it is a strong dependence. In contrast, the correlation between copper production and other factors is very strong and positive. Using econometric modeling, it was discovered that exponential regression is the best expression for the relationship between copper production and its price and logarithmic regression most appropriate for the relationship between copper production and all other economic factors.

Keywords: *econometric model, world copper production, economic factors, Pearson correlation coefficient*

Introduction

Copper has been known since prehistoric time. It has been mined for more than 5000 years. Mankind has used the metal since at least 9000 BC in the Middle East. A copper pendant dated to 8700 BC was found in Iraq. Scientists believe only iron from meteorites and gold were used by people earlier than copper. The idea that there was a Copper Age between the Neolithic and Bronze Age was inspired by the discovery of the use of native copper in prehistoric North America. Its currency in European prehistory owes much to the 1861 observations by William Wilde that copper tools preceded the use of bronze in Ireland [1].

Copper is widely used in the electrical industry. The possible shortage of copper on the market is thus an important aspect affecting the development of electromobility and the entire energy infrastructure. In addition to many other uses, copper is used in plumbing and for cookware. Brass and bronze are two important copper alloys. Copper compounds are toxic to invertebrates and are used as algicides and pesticides. Copper compounds are used in analytical chemistry, as in the use of Fehling's solution to test for sugar. American coins contain copper. Sometimes copper appears in its native state. It is found in many minerals, including malachite, cuprite, bornite, azurite, and chalcopyrite. Copper ore deposits are known in North America, South America, and Africa [2].

Literary sources that deal with copper are very rich and varied. The inspiration of the authors of the article was those sources that model the interrelations between copper parameters (price, supply, demand, etc.) and determinants that influence these parameters. These literary sources are also very rich and diverse. These include, for example, modelling the supply of recycled material (copper) on historical consumption [3], analysing factors determining the level and dynamics of world copper prices by testing hypotheses on the dependence of fluctuations in the world copper market [4], a theoretical model of copper price cartel behaviour during the boom and recession [5], modelling GDP forecasts for various commodities including copper [6], modelling of the impact of financial and economic crises on copper mining companies' performance indicators [7], reviewing the dynamic transformational characteristics of the joint impact of gold and oil on long-term copper returns [8], forecasting copper production by 2035 in Chile on the basis of knowledge of potential mining projects, reserves and resources [9], determining the chaotic behaviour of copper prices over a long period using annual prices [10], analysis and quantification of how the mining industry in Chile affects other macroeconomic variables [11], modelling of the price and income elasticity of minerals [12], analysis of determinants of countries' competitiveness in attracting mining investment [13] and analysis of causality between metal prices [14].

Due to the importance of copper for the current and future development of the domestic and world economies, as well as the lack of quantification of the impact of selected economic factors on world copper production according to different types of regressions in the scientific literature, the authors of the article decided to take a closer look at this issue.

The macroeconomic findings show that demand (or world production) for any raw material depends not only on its price, but also on the population, the GDP, the price of other

Tab. 1. Time series of economic factors and world copper production between 2010 and 2019
Tab. 1. Swiatowa produkcja miedzi a czynniki ekonomiczne w latach 2010–2019

Period	Price (CZK/kg)	Population	GDP per capita ($)	Inflation (%)	Cumulative inflation (%)	Copper production (t)
2010	183.83	6,956,823,603	13,904.63	3.36	100.00	15,900
2011	151.05	7,041,194,301	14,275.46	4.81	104.81	16,100
2012	153.29	7,125,828,059	14,554.85	3.69	108.68	16,900
2013	148.90	7,210,581,976	14,857.76	2.59	111.49	18,300
2014	142.19	7,295,290,765	15,189.65	2.35	114.11	18,500
2015	116.79	7,379,797,139	15,516.99	1.43	115.74	19,100
2016	141.71	7,464,022,049	15,837.38	1.50	117.48	20,100
2017	154.55	7,547,858,925	16,253.39	2.18	120.04	20,000
2018	130.73	7,631,091,040	16,636.42	2.44	122.96	20,400
2019	139.51	7,713,468,100	16,911.19	2.18	125.59	20,400

Tab. 2. Indicator of strength of correlation by Evans (1996)
Tab. 2. Wskaźniki siły korelacji wg Evans (1996)

correlation coefficient (R) value	strength of correlation
between ± 0,8 to ± 1,00	very strong correlation
between ± 0,6 to ± 0,79	strong correlation
between ± 0,4 to ± 0,59	moderate correlation
between ± 0,2 to ± 0,39	weak correlation
between ± 0,0 to ± 0,19	very weak correlation

products and services and other economic factors [15]. Two objectives are formulated in the article.

The first objective is to determine the impact of economic factors on world copper production. The second objective is to create econometric models that best express the dependence of world copper production on economic factors. The period 2010 to 2019 was chosen for the period under investigation. Economic factors were chosen as the factors examined: the average annual world price of copper, the size of the world's population, the size of world GDP per capita in purchasing power parity, and cumulative inflation expressing the impact of other prices of products and services.

Within the first objective, 2 hypotheses were proposed:

- H1: The correlation between world copper production and its average annual price is negative and moderately strong.
- H2: The correlation between world copper production and world population, world GDP per capita, cumulative inflation is very strong and positive.
- Within the second objective, 2 hypotheses were proposed:
- H3: An econometric model representing the relationship between world copper production and its average annual price is best expressed by power regression.
- H4: An econometric model representing the relationship between world copper production and other economic factors (population, GDP, cumulative inflation) is best expressed by linear regression.

Materials

The data were used from publicly available Internet servers and databases such as World Bank, US Government, the Observatory of Economic Complexity. The data base (see Table 1) for the realization of both research objectives consists of a time series of economic factors under the study (average annual copper price, world population size, world GDP per capita in purchasing power parity, annual inflation, cumulative inflation) and a time series of world copper production between 2010 and 2019.

The input data clearly shows that economic factors such as population, GDP and cumulative inflation represent growing purely monotonous functions between 2010 and 2019. At the same time, the trend of world copper production is a growing function with a slight decline in 2017. Based on these inputs, the authors defined the hypothesis H2 and H4. On the contrary, the time series of average annual copper prices is very volatile. Hypotheses H1 and H3 were therefore established from this finding.

Methods

Correlation analysis was used to achieve the first objective of the article. The method of correlation analysis determines the strength of impact of the investigated economic indicators on the EU internal demand for critical raw materials. Correlation analysis expresses the degree of linear dependence of two random variables. It is often referred to the Pearson's correlation coefficient as a means of quantifying the degree of independence [16]. The coefficient is defined as follows:

$$R(X,Y) = E\left(\frac{X - E(X)}{\sqrt{D(X)}} \cdot \frac{Y - E(Y)}{\sqrt{D(Y)}}\right) \quad (1)$$

Where, there are
X, Y – random variables; E – mean value; D – variance; R (X, Y) – Pearson's correlation coefficient.

Pearson´s correlation coefficient ranges from −1 to 1. A value of 1 implies that a linear equation describes the relationship between X and Y perfectly, with all data points lying on a line for which Y increases as X increases. A value of −1

Tab. 3. Correlation analysis of world copper production and economic factors under analysis
Tab. 3. Analiza korelacji produkcji miedzi w świecie i wskaźników ekonomicznych

	Price	Population	GDP per capita	Cumulative inflation
World copper production	-0.64	0.97	0.96	0.97

Tab. 4. Determination coefficient by econometric models and types of regression
Tab. 4. Wyznaczone współczynniki korelacji dla modeli regresyjnych

Econometric model / Regression	Exponential	Linear	Logarithmic	Power
Copper production=f(price)+u	0,4233	0,409	0,3843	0,3977
Copper production=f(population)+u	0,9277	0.9377	0,9428	0,9336
Copper production=f(GDP)+u	0,9078	0,9194	0,9303	0,92
Copper production=f(cumulative inflation)+u	0,9319	0,9345	0,9372	0,9365

implies that all data points lie on a line for which Y decreases as X increases. A value of 0 implies that there is no linear correlation between the variables.

The calculation of the Pearson correlation coefficient was performed in MS Excel using the PEARSON() function. The outputs of the first objective are processed in the Table 3.

The evaluation of the H1 and H2 hypotheses was carried out according to the correlation strength indicator (Table 2) by the Evans classification (1996).

Econometric modelling was used to achieve the second objective of the article. Econometric models are statistical models used in econometrics. An econometric model specifies the statistical relationship that is believed to hold between the various economic quantities pertaining to a particular economic phenomenon. An econometric model can be derived from a deterministic economic model by allowing for uncertainty, or from an economic model which itself is stochastic. However, it is also possible to use econometric models that are not tied to any specific economic theory.

In general, the econometric model can be written as follows

$$y_t = f(b_0, b_1, \dots, b_n, x_t) + e_t \tag{2}$$

Where there are
y_t – dependent (explained) variable. In our case, it is a world-class copper production; x_t – independent (explanatory) variable. In our case, it is one of the economic factors (price, population, GDP, cumulative inflation);b_0,b_1…b_n – regression coefficients. Regression coefficients are determined by regression analysis; e_t – residual component. If the residual component equals zero it is obtained a functional relationship between the explained and explanatory variables.

As already mentioned, different types of regression analyses are used to determine regression coefficients. It depends on the relationship between the explained and the explanatory variable. Therefore, we distinguish linear or nonlinear types of regression. The authors used four types of regressions in the article. They also used MS Excel graphics tools to perform them. These were regressions exponential, linear, logarithmic and power.

The exponential regression

$$\ln(y) = \ln(b_0) + b_1.x \tag{3}$$

The linear regression

$$y = b_0 + b_1.x \tag{4}$$

The logarithmic regression

$$y = b_0 + b_1.\ln(x) \tag{5}$$

The power regression

$$\ln(y) = \ln(b_0) + b_1.\ln(x) \tag{6}$$

As a measure of the quality of the econometric model, a coefficient of determination is used in mathematical statistics. The coefficient of determination, commonly referred to as R^2 ("R square") in its basic form expresses what proportion of the variability of the explained variable the model explains. The coefficient of determination can take values at most 1 (or expressed as a percentage of 100%), which means a perfect prediction of the values of the explained variable. Conversely, a value of 0 (or 0%) means that the model does not provide any information for recognizing the explained variable, it is completely useless. The results of the second objective of the article are shown in Table 4 and Figures 1, 2, 3 and 4.

Results and Discussion

The results of the implementation of the first objective of the article (Table 3) show that the correlation between the world's copper production and its price is negative and strong (0.64). This leads to the rejection of the H1 hypothesis due to the finding of a strong correlation. However, the value of this correlation is located at the bottom edge for a strong correlation. For all other economic factors, there was recorded positive and very strong correlation (>0.95) with world copper production. The H2 hypothesis was therefore accepted.

Under the second objective, four econometric models (the first column of Table 4) were created to express the dependence of world copper production on the economic factors under investigation. Each model was created according to four types of regressions (exponential, linear, logarithmic

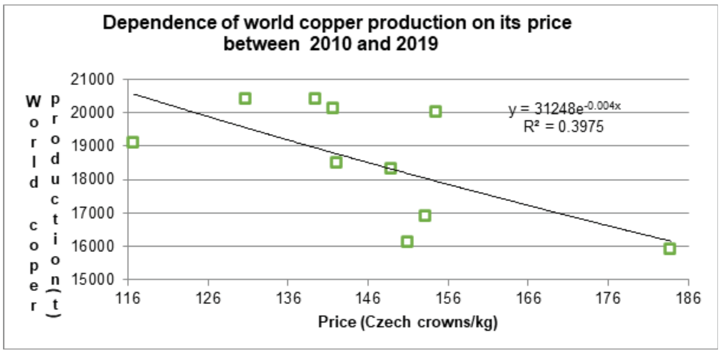


Fig. 1. The best econometric model of the dependence of world copper production on its price
Rys. 1. Najlepszy model ekonometryczny zależności produkcji miedzi i jej ceny

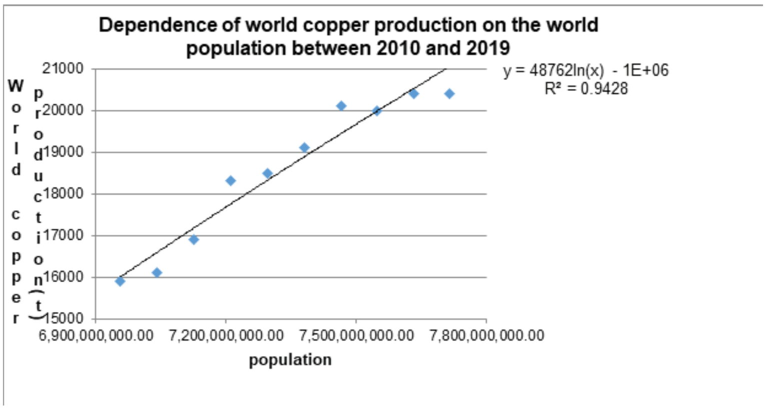


Fig. 2. The best econometric model of the dependence of world copper production on world population
Rys. 2. Najlepszy model ekonometryczny zależności produkcji miedzi od populacji na świecie

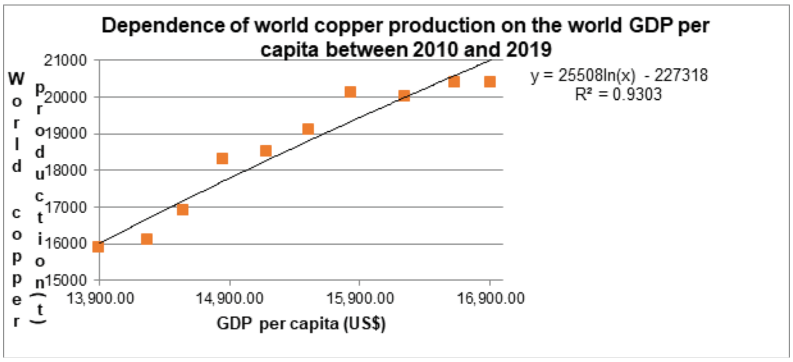
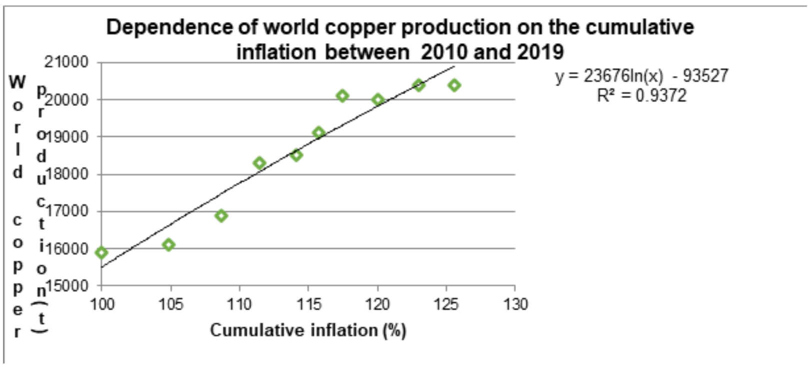


Fig. 3. The best econometric model of the dependence of world copper production on world GDP per capita
Rys. 3. Najlepszy model ekonometryczny zalezności produkcji miedzi od światowego produktu narodowego brutto (GDP)



Tab. 1. Time series of economic factors and world copper production between 2010 and 2019
Tab. 1. Swiatowa produkcja miedzi a czynniki ekonomiczne w latach 2010–2019

and powerful). Thus, a total of 16 econometric models were created, for each economic factor of 4 models. The quality of these models was assessed according to the coefficient of determination R2 (Table 4).

The results of the second objective of the article clearly show that the values of the coefficient of determination for all econometric models expressing the dependence of world copper production on its price are very low and do not change much according to the type of regression used. The best determination coefficient value was achieved by an econometric model created by exponential regression (Table 4-green highlighted, Figure 1). The H3 hypothesis cannot therefore be accepted. In contrast, the determination coefficient values for all econometric models expressing the dependence of world copper production on all other economic factors studied are very high and practically do not differ at all according to the type of regression used (Table 4). The best determination coefficient values for all other economic factors were achieved by econometric models created by logarithmic regression (Table 4-green highlighted. The H4 hypothesis must be rejected. The best econometric models, including their equations, are shown in Figures 1, 2, 3 and 4.

The results of the research clearly show a significant difference between the effect of the price on world copper production (Table 3) and the influence of other factors on this production. Factors such as the world's population, world GDP, and cumulative inflation are proving to have a significant impact on world copper production. Based on econometric modelling, it showed out that the price as an economic factor according to the coefficient of determination insufficiently explains (Table 4) the impact on the overall world copper production between 2010 and 2019. In contrast, all other factors according to this coefficient almost perfectly explain (Table 4) their impact on world copper production.

By comparing the application of different types of regression through the coefficient of determination, only small differences (Tabel 4) between them were found. However, account should be taken of the fact that if the research had been carried out for another time period, the regression coefficient values would have been different. However, this is the problem of all econometric models. The authors believe that, given the stable growth of copper production in the world, as well as the growth of economic factors such as the world's population, world GDP, and cumulative inflation (Table 1), these differences will be minimal.

According to the results of the research, the authors concluded that the average annual world price of copper, given its volatility, insufficiently explains its impact on world copper production and therefore do not recommend using it in one-dimensional econometric models to predict the development of world copper production. On the contrary, according to the authors, all econometric models explaining the impact of other factors studied on world copper production can be used for practical use for its prediction.

Conclusion

The research carried out clearly shows that between 2010 and 2019 there is a very strong relationship between world copper production and economic factors such as the world population, world GDP per capita in purchasing power parity and cumulative inflation. Econometric models that express this relationship regardless of what type of regression has been used show a very high determination coefficient value. Although for another period of time, economic models would have slightly different regression coefficients, given the stability of these economic factors and world copper production, these factors explain this production quite sufficiently. Therefore, the authors recommend using these econometric models for short and medium-term predictions and updating them regularly after this time.

Research has also clearly shown that the average annual world copper price does not adequately explain the impact on world copper production. Econometric models expressing the influence of the world copper price on its production have a very low coefficient of determination. Therefore, they are not suitable for prediction. The authors believe that this is mainly due to price volatility over time, caused by uneconomic factors such as political interests, lobbying interests and other factors.

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Wpływ czynników ekonomicznych na światową produkcję miedzi

Miedź jest bardzo ważnym minerałem, który ma szerokie zastosowanie w przemyśle, zwłaszcza w elektrotechnice i energetyce. Wraz ze wzrostem elektromobilności jej potencjał będzie rósł w przyszłości. Wszelki niedobór miedzi na rynku światowym mógłby zatem zagrozić nowoczesnemu przemysłowi. W związku z tym autorzy postanowili zająć się wpływem czynników ekonomicznych (cena, ludność, PKB i skumulowana inflacja) na produkcję miedzi oraz stworzyć odpowiednie modele ekonometryczne, wyrażające zależność między produkcją a czynnikami ekonomicznymi dla okresu 2010-2019. Wpływ czynników ekonomicznych na światową produkcję miedzi badany jest za pomocą współczynnika korelacji Pearsona. Stwierdzono, że produkcja miedzi jest odwrotnie proporcjonalna do ceny miedzi, jest to silna zależność. Natomiast korelacja między produkcją miedzi a innymi czynnikami jest bardzo silna i pozytywna. Korzystając z modelowania ekonometrycznego, odkryto, że regresja wykładnicza jest najlepszym wyrażeniem relacji między produkcją miedzi a jej ceną, a regresja logarytmiczna najbardziej odpowiada relacji między produkcją miedzi a wszystkimi innymi czynnikami ekonomicznymi. .

Słowa kluczowe: *model ekonometryczny, światowa produkcja miedzi, czynniki ekonomiczne, współczynnik korelacji Pearsona*