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Non-Ferrous Metals Market – a Bibliometric Analysis

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Abstract

Theoretical background: Non-ferrous metals are important in many areas of the economy, and their prices are sensitive to crisis situations such as wars and regional conflicts, as well as changes in the political situation. Demand for non-ferrous metals is constantly growing, because with increasing wealth, technical and technological progress, both the demand from existing uses of these metals and this related to their new applications are increasing. The role of non-ferrous metals is due to their diverse applications.
Purpose of the article: The aim of the article is to identify the current scientific achievements on the market of non-ferrous metals and investments in non-ferrous metals. This will allow to systematize knowledge about the non-ferrous metals market and indicate the current state of knowledge in this area.
Research methods: Bibliometric analysis was used in the article. A critical review of the world literature on the market and investments in non-ferrous metals has been conducted. The PRISMA technique was used in the study. The study was conducted on the basis of literature published between 2000 and 2023 and available in the Scopus.
Main findings: Issues related to the non-ferrous metals market and investments in them are considered in the world literature. The popularity of this subject has been increasing in recent years. The publications used mainly forecasting methods, descriptive statistics, Granger's causality issues and GARCH models. Among researchers dealing with the subject of the non-ferrous metals market and investments in these metals, there are few authors from Central and Eastern Europe, including Poland. This translates into

a small number of publications and citations from scientists in the region. As a result, the specificity of the non-ferrous metals market and investments in non-ferrous metals in Poland and other Central and Eastern European countries is not examined. Therefore, it is not known how changes in this market affect the economic situation of the countries of Central and Eastern Europe. In addition, the properties of non-ferrous metals are analysed primarily taking into account the properties of crude oil. The conclusions contained in the article will be useful primarily to scientists. Thanks to the critical literature review, they will be able to get acquainted with the current state of knowledge in the area of the non-ferrous metals market, and on this basis assess the current state of knowledge in this area and plan further research directions. In subsequent studies, it is worth conducting a bibliometric analysis of the literature available in databases other than Scopus and non-English language positions. It will be valuable to compare the results obtained using keywords and restrictions set during the conducted research with the results obtained using other, close-meaning keywords.

Introduction

Non-ferrous metals are metals that do not contain iron in their composition (Bylica et al., 2014). They are important raw materials because the resources of these metals are non-renewable and the stocks of these metals are limited. Due to limited stocks, some of the non-ferrous metals, such as copper and nickel, have been considered as critical and strategic raw materials (Regulation (EU) 2024/1252…, 2024).

The role of non-ferrous metals is due to their diverse applications. Mercury is the only non-ferrous metal whose importance in the economy has decreased significantly (Paulo & Strzelska-Smakowska, 2020). All other non-ferrous metals continue to be in high demand, which for some metals is even increasing with technical and technological advances and the associated new uses of these raw materials. As a result, the production of non-ferrous metals in the world is constantly growing, and consequently the market for these raw materials is growing.

The aim of this article is to identify the current scientific achievements related to the non-ferrous metals market as well as investments in these metals. Research methods such as literature review and bibliometric analysis are used in the literature. However, previous literature reviews have focused on other aspects of economics and finance, for example: sustainable marketing (Adamczak et al., 2024), quality of logistics services on the plastics market (Przęczek & Majchrzak, 2024), ESG activities in cooperative banks (Korzeb et al., 2024). Identification the current scientific achievements related to the non-ferrous metals market as well as investments in these metals will allow to systematize knowledge about the non-ferrous metals market and indicate the current state of knowledge in this area.

The structure of the article is subordinated to the achievement of the above goal. The first part of this study describes the research methods that were used. The next one presents the results of bibliometric analysis of publications focused on the non-ferrous metals market published between 2000 and 2023.

Literature review

The subject of non-ferrous metals is discussed in the world literature. Usually, this subject is considered in the context of issues related to chemistry, materials science, engineering, environmental protection or medicine. Much less often, the subject of non-ferrous metals is considered from an economic or financial point of view. Literature reviews on economic issues related to non-ferrous metals, including bibliometric analysis of scientific literature, are also not often conducted.

In the years 2000–2023, Scopus published 3,259 English-language publications related to economics and finance that used bibliometric analysis as a research method (the phrase "bibliometric analysis" was used in the title or as a keyword). These publications included one article in which a bibliometric analysis of the available literature in the field of metals in the economics context was carried out (Zhang et al., 2019). However, the subject of this article focused on the bibliometric analysis of the literature on urban mining, and the literature on metals was analysed only in this aspect. During this period, no articles were published that would refer to the review of the literature related to non-ferrous metals in economics and finance.

In Polish journals, despite the popularity of bibliometric analysis, this method has not been used to identify the state of knowledge about the market and investment in non-ferrous metals. Between 2000 and 2023, 151 publications both English and Polish, in which bibliometric analysis was used, were identified in the Bazekon database (2024). These publications deal with various topics related to economics, finance and management, but did not deal with topics related to metals. Also in the pages of the journal *Annales Universitatis Mariae Curie-Skłodowska, sectio H – Oeconomia* were published articles in which bibliometric analysis was used as a research method (the phrase "bibliometric analysis" or "bibliometric methods" was among the keywords or in the title). In recent years there have been three articles. One of them concerned social media releases and stock performance (Byrka-Kita & Gola, 2023), the second one was about marketing research (Więcek-Janka & Szewczuk, 2022), while the third was focused on intellectual capital (Smuda-Kocoń, 2022). The bibliometric analysis of issues related to economics and finance is therefore carried out, but the previous research did not take into account issues related to the market and investments in non-ferrous metals.

Research methods

A critical review of the world literature on the non-ferrous metals market and investments in these metals has been performed. This database was searched narrowing down the search results to the following terms found in the title, abstract or listed as keywords: non-ferrous metals or base metals (due to the similar range of metals that are defined as base and non-ferrous metals), combined with the occurrence of

words found in the title, abstract or listed as keywords: investment or market. The search was narrowed down to publications published in English since 2000, as well as publications in business, economics and mathematics. The literature review was carried out using the PRISMA technique (Page et al., 2021) (Figure 1).

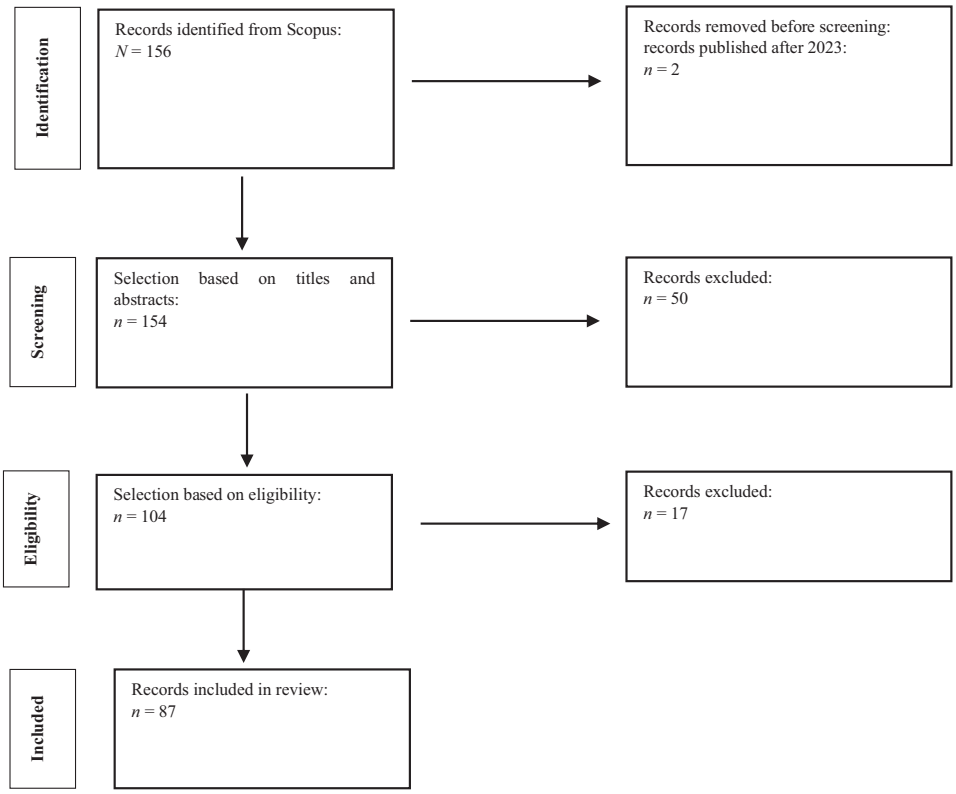

Figure 1. PRISMA diagram

Source: Author's own study based on (Scopus data, 2023).

Based on the set search conditions, 156 publications were found in the Scopus database (Figure 1). In the first stage, two of them were rejected due to an inappropriate time range, as they were published after 2023. Thus, 154 publications qualified for the screening stage. At this stage, 50 items were removed. These publications were excluded from the analysis when, based on the title and abstract, it was determined that they were not relate to the subject matter studied. On this basis, items that did not deal with economic and financial issues, but with aspects of chemistry and materials engineering, in particular, were excluded. The next stage was the eligibility stage, for which 104 items were qualified. At this stage, another 17 publications were excluded on the basis of article texts. The excluded publications usually touched on economic

aspects, but they were not related to the metals market or metal investments. As a result, 87 publications were included in the analysis. The study was conducted using Microsoft Excel and VosViewer tool.

Results

After selection, 87 publications were included in further analyses. All publications came from the Scopus database. They were published between 2000 and 2023 (Figure 2).

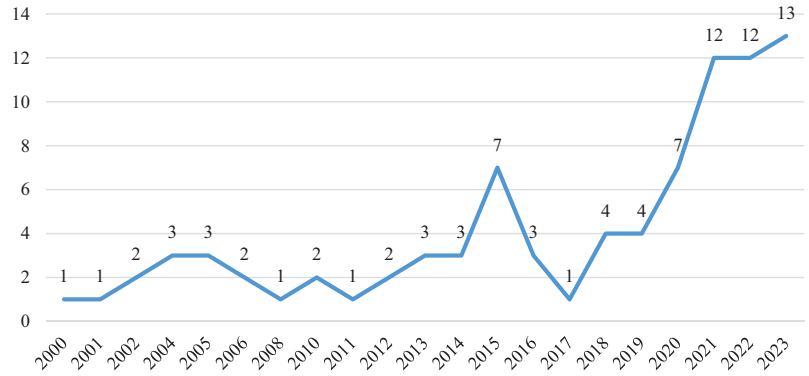

Figure 2. Number of the studies on the non-ferrous metals market published between 2000 and 2023

Source: Author's own study based on (Scopus data, 2023)

The number of publications varied from year to year. However, there is an upward trend in the number of publications on the non-ferrous metals market. There has been an increase in interest in the subject of non-ferrous metals during recent crises, such as the COVID-19 pandemic and the war in Ukraine. In addition, in the years under review, the largest number of publications on this topic were published in 2023. This indicates an increase in interest in this topic among researchers, as well as its growing importance.

The 87 publications included in the analysis were prepared by a total of 177 authors. The largest number of publications was by N. Todorova, who published seven articles. Five papers were prepared by M. McAleer and C. Watkins each. The authors who published four publications each were: J. Chen, I. Haine, A. Omura and X. Zhu. Three publications were prepared by Y. Chen, R. Chung and B. Li. Two publications were published by: P. Berry, E. Bouri, I. Figuerola-Ferretti, J.A. Galán-Gutiérrez, S. Ghosh, B.A. Goss, K. Kanjilal, H. Li, Z. Liu, R. Martín-García, A. Maurer, W. Mensi, W. Mollard, M.U. Rehman, S. Richmond, X.V. Vo, J. Wang, L. Zhang and D. Krężołek. Some of the publications were co-authored (Figure 3, Figure 4).

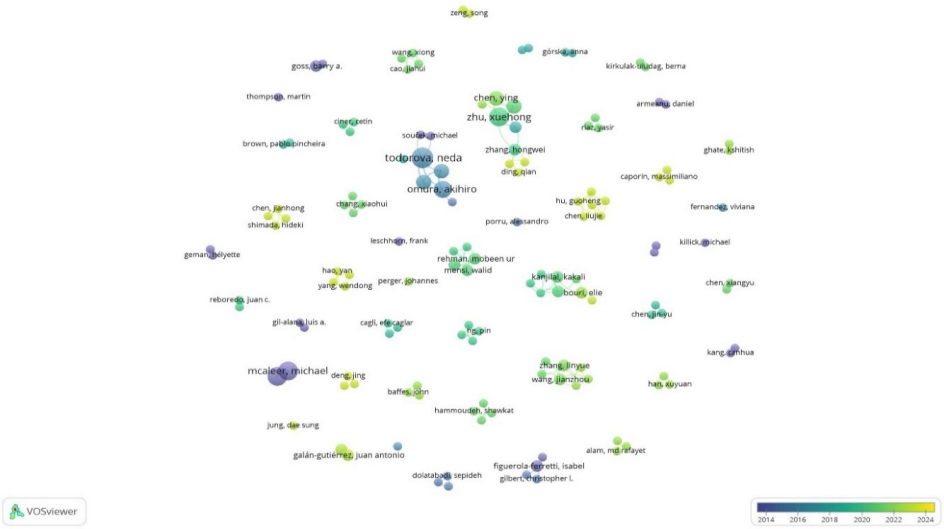

Figure 3. Co-authorship of publications – cooperation between authors

Source: Author's own study based on (Scopus data, 2023).

Publications co-authored were created rather in certain groups, in which the authors decided to co-author, but these groups did not overlap with each other personally. Thus, mutual connections in terms of co-authors existed in many groups of several people which were not affiliated with each other. At the beginning of the period under study, there were no publications co-authorship on the researched topic. It was not until around 2014 that the first co-authorship publications began to be published. Since then, co-authorship publications have been published regularly, although the groups in which authors publish have changed over time.

Despite the fact that the mutual connections in terms of co-authors did not permeate each other, taking into account not individual authors, but their nationality, transnational cooperation can be observed. The largest number of co-authored publications were written by scientists from China (23 publications) and Australia (17 publications). In the years 2014–2017, publications in co-authorship were prepared primarily by authors from the United Kingdom, Australia and New Zealand. In later years, publications in co-authorship were created by scientists from Poland, Russia, the United States and India. The most recent publications in co-authorship are published by scientists from China, Japan and South Korea. Thus, certain change in the preparation of publications in co-authorship can be noticed, because in previous years such publications were created mainly with the participation of scientists from the Western community, in later years with the participation of scientists from Central and Eastern Europe, and now primarily with the participation of authors from Asian countries.

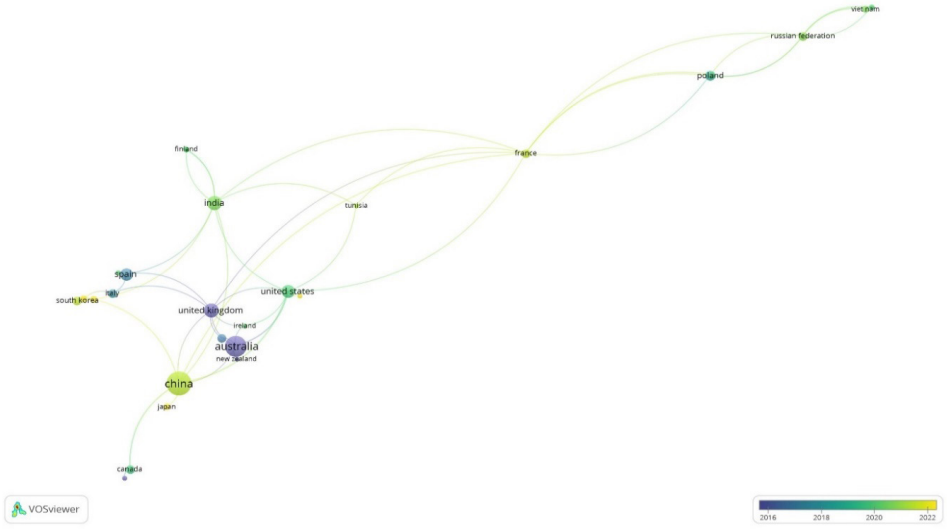

Figure 4. Co-authorship of publications – cooperation between countries

Source: Author's own study based on (Scopus data, 2023).

Among the countries, seven groups can be distinguished in which authors most often cooperate with each other. The first group includes: Brazil, Iran, Lebanon, South Korea, Italy and Spain. The second group includes: Australia, New Zealand, Germany, Ireland and the United Kingdom. The third group includes: China, Japan, Canada and Denmark. The fourth group includes: Finland, India, Norway and Sweden. The fifth group includes: France, Poland, Pakistan and the United Arab Emirates. The sixth group includes: Oman, Qatar, Vietnam and Russia, while the seventh group includes: Bangladesh, Tunisia and the United States. Thus, it can be seen that cooperation between countries includes countries that differ in terms of location or political system. The connections between countries have also changed over the years. Authors from Australia and the United Kingdom published the largest number of co-authored publications around 2016. Later, Spaniards and Italians began to publish, followed by scientists from Ireland, Finland, Polish, Canada and the United States. Currently, the largest number of co-authored publications are published by French, Tunisians, Chinese, Japanese and South Koreans.

Papers on non-ferrous metals have been published primarily in journals. Issues containing publications on the non-ferrous metals market, along with the number of publications on this issue in the years 2000–2023, as well as rankings of journals are presented in Table 1. For all journals, their rankings are shown: the Web of Science Journal Info (WoS IF), Scimago Journal & Country Rank (SJR) (in which a journal is ranked the better it is, the higher it has achieved) and ABDC Journal Quality List (ABDC) (in which the worst ranked journals receive a C, while the best receive an A*).

Table 1. Publications on the non-ferrous metals market

No.	Title	WoS IF	Scopus SJR	ABDC	Number of articles
1	*Applied Economics*	1.916	0.590	A	1
2	*Applied Economics Letters*	1.287	0.450	B	1
3	*Australian Commodities*	-	-	C	5
4	*Australian Economic Papers*	1.452	0.480	B	1
5	*Australian Journal of Agricultural and Resource Economics*	3.200	0.830	-	1
6	*Base Metals Handbook*	-	-	-	1
7	*Business Management*	-	-	-	1
8	*Commodity Derivatives: Markets and Applications, Second Edition*	-	-	-	1
9	*Economic Modelling*	3.875	1.303	A	2
10	*Energy*	9.000	1.989	-	2
11	*Energy Economics*	12.800	3.039	A*	4
12	*Finance Research Letters*	10.400	2.231	A	3
13	*Futures Markets: Their Establishment and Performance*	-	-		1
14	*Global Finance Journal*	2.853	0.775	A	1
15	*Handbook of Multi-Commodity Markets and Products: Structuring, Trading and Risk Management*	-	-	-	1
16	*International Journal of Emerging Markets*	3.422	0.532	B	1
17	*International Journal of Finance and Economics*	-	0.606	-	1
18	*International Journal of Financial Studies*	2.300	0.377	B	1
19	*International Review of Financial Analysis*	8.235	1.881	A	1
20	*Journal of Commodity Markets*	3.317	0.737	A	2
21	*Journal of Econometrics*	6.300	5.744	A*	1
22	*Journal of Economic Surveys*	4.142	2.199	A	1
23	*Journal of Futures Markets*	2.350	0.724	-	1
24	*Journal of International Financial Markets, Institutions and Money*	-	1.031	A	1
25	*Journal of Quantitative Economics*	0.000	0.253	B	1
26	*Journal of System and Management Sciences*	-	0.225	-	1
27	*Journal of Time Series Analysis*	0.900	0.967	A	1
28	*Mathematics*	2.400	0.446	-	2
29	*Mathematics and Computers in Simulation*	4.600	0.755	-	3
30	*Mineral Economics*	0.000	0.488	C	1
31	*MODSIM 2005 – International Congress on Modelling and Simulation: Advances and Applications for Management and Decision Making, Proceedings*	-	-	-	1
32	*Oxford Economic Papers*	1.152	0.615	A	1
33	*Proceeding of 2012 International Conference on Information Management, Innovation Management and Industrial Engineering, ICIII 2012*	-	-	-	1
34	*Proceedings of the 31st International Business Information Management Association Conference, IBIMA 2018: Innovation Management and Education Excellence through Vision 2020*	-	-	-	1
35	*Recycling Today*	-	-	-	1
36	*Resources Policy*	10.200	1.869	B	28
37	*Romanian Journal of Economic Forecasting*	0.963	0.234	C	1
38	*Scrap*	-	-	-	1

No.	Title	WoS IF	Scopus SJR	ABDC	Number of articles
39	*Statistics in Transition New Series*	-	-	-	1
40	*Studies in Classification, Data Analysis, and Knowledge Organization*	-	-	-	1
41	*Sustainable Investing for Institutional Investors: Risks, Regulations and Strategies*	-	-	-	1
42	*Systems*	1.900	0.483	-	1
43	*Thailand and the World Economy*	-	0.140	-	1
44	*The Handbook of Commodity Investing*	-		-	1
45	*World of Mining – Surface and Underground*	-	0.104	-	1

Source: Author's own study based on (Scopus data, 2023; Web of Science Journal Info, 2023; Scimago Journal & Country Rank, 2023; ABDC Journal Quality List, 2023).

The largest number of articles on the non-ferrous metals market was published in the journal *Resources Policy*, which published 28 articles on the subject. Studies concerning this topic have also been published in *Australian Commodities* (five articles). Four papers were published in *Energy Economics*, three each in *Finance Research Letters* and *Mathematics and Computers in Simulation*. Two papers were published in *Energy*, *Economic Modelling*, *Journal of Commodity Markets* and *Mathematics*. In the other editions listed in Table 1, one publication was published in the area of the non-ferrous metals market.

Of the 87 publications, most were published in journals indexed in the Web of Science Journal Info (WoS IF), Scimago Journal & Country Rank (SJR) and ABDC Journal Quality List (ABDC). The WoS IF ranking indexed journals in which 63 analysed articles were published. The average WoS IF index for these publications reached the value of 7.32. In this ranking, the following journals received the highest scores: *Energy Economics* (WOS IF = 12.8), in which 1 article on the non-ferrous metals market was published, *Finance Research Letters* (WOS IF = 10.4), in which four articles were published, and *Resources Policy* (WOS IF = 10.2), in which 28 articles on the non-ferrous metals market were published. The SJR ranking indexed journals in which 68 items were published. The average SJR index was 1.50. The highest SJR ratios were achieved by the following journals: *Journal of Econometrics* (SJR = 5.744), in which one article was published, *Energy Economics* (SJR = 3.039), in which 4 articles were published, and *Finance Research Letters* (SJR = 2.231), in which three articles on the non-ferrous metals market were published. The ABDC ranking indexed journals in which 59 analysed articles were published. The highest scores were: *Journal of Econometrics* (one article) and *Energy Economics* (four articles). Both journals were rated with the best score: A*. In their work, the authors drew on the achievements of other researchers (Figure 5, Figure 6).

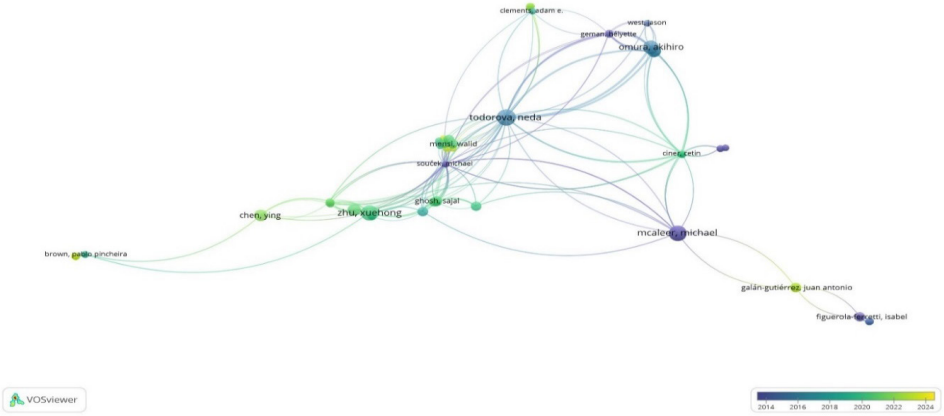

Figure 5. Citations – authors

Source: Author's own study based on (Scopus data, 2023).

The largest number of citations were recorded by N. Todorova's publications (124 citations). Not much less (103 times) were cited the publications of X. Zhu, cited in later years than N. Todorova. N. Todorova, M. McAleer, and A. Omura were cited primarily in 2014–2017, with W. Mensi, X. Zhu, and S. Ghosh cited in subsequent years. In recent years, Y. Chen, P. Brown, and J.A. Galán-Gutiérrez were cited primarily.

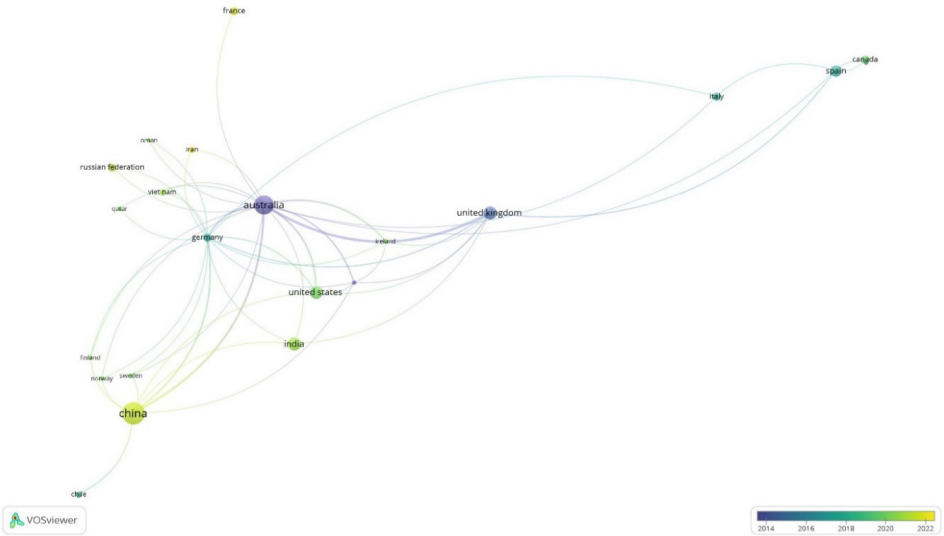

Figure 6. Citations – countries

Source: Author's own study based on (Scopus data, 2023).

When considering cross-country citations, Chinese publications were cited the most times (297). Spanish (238) and Australian (224) publications were cited slightly fewer times. Polish publications have been cited 34 times. Publications by researchers from Australia and the United Kingdom were the most cited in 2014–2016. In subsequent years, Italian, Spanish and German publications were more frequently cited. As of 2020, publications by authors from Canada, the United States, India and Russia were more frequently cited. Currently, Chinese publications are the most cited.

Countries can be divided into nine groups according to their mutual citations. The first group includes Canada, Denmark, Italy and Spain. The second one: Chile, China, Finland and Sweden. Germany, Iran, Oman and Qatar are the third group, Ireland, New Zealand and the United States are fourth. Australia and France were included in the fifth group, when India and the United Kingdom were classified in the sixth group. Three single-object groups were also distinguished: Norway, Russia and Vietnam. Australian and British papers were cited the earliest, peaking around 2014, followed by Italian, Spanish, German, and Chilean papers cited in the following years. This was followed by citations from India, the United States, Vietnam, and Russia. Currently, Iranian, French and Chinese studies are the most frequently cited. Papers on the non-ferrous metals market were mostly publications containing the results of empirical research (Table 2).

Table 2. Type of publication

Type	Publication
Critical literature review	(Schofield, 2021); (Watkins & McAleer, 2004)
Empirical research	(Deng et al., 2023); (Ding et al., 2023); (Galán-Gutiérrez et al., 2023); (Ghazani et al., 2023); (He & Huang, 2023); (Hu et al., 2023); (Jung, 2023); (Kamal & Bouri, 2023); (Shu et al., 2023); (Wang et al., 2023); (Yang et al., 2023); (Zhang & Zeng, 2023); (Zhao et al., 2023); (Alam et al., 2022); (Baffes et al., 2022); (Bamba et al., 2022); (Chen, Chen et al., 2022); (Chen, Li et al., 2022); (Galán-Gutiérrez & Martín-García, 2022); (Guo et al., 2022); (Han et al., 2022); (Kumar & Dhiman, 2022); (Mishra & Ghate, 2022); (Nag et al., 2022); (Perger, 2022); (Chen & Tongurai, 2021); (Hsu, 2021); (Khalfaoui et al., 2021); (Kirkulak-Uludag & Safarzadeh, 2021); (Mensi et al., 2021); (Song et al., 2021); (Umar et al., 2021); (Wang D. et al., 2021); (Wang J. et al., 2021); (Wen et al., 2021); (Zhu et al., 2021); (Al-Yahyaee et al., 2020); (Ciner et al., 2020); (Krężołek, 2020); (Reboredo & Ugolini, 2020); (Shen et al., 2020); (Watkins & McAleer, 2020); (Yahya et al., 2020); (Brown & Hardy, 2019); (Cagli et al., 2019); (Chen et al., 2019); (Zhou et al., 2019); (Górska & Krawiec, 2018); (Omura et al., 2018); (Park & Lim, 2018); (Todorova & Clements, 2018); (Lyócsa et al., 2017); (Fernandez, 2016); (Krężołek, 2016); (Omura et al., 2016); (Dolatabadi et al., 2015); (Figuerola-Ferretti et al., 2015); (Omura & West, 2015); (Omura et al., 2015); (Posch et al., 2015); (Todorova, 2015); (Dinică & Armeanu, 2014); (Gil-Alana & Tripathy, 2014); (Todorova et al., 2014); (Geman & Smith, 2013); (Goss &Avsar, 2013); (Goss, 2013); (Sun & Kang, 2012); (Copeland & Beaini, 2010); (Figuerola-Ferretti & Gonzalo, 2010); (Watkins & McAleer, 2008); (Leschhorn, 2006); (Garino, 2005); (Long-term strength, 2005); (Watkins & McAleer, 2005); (Mollard et al., 2004a); (Mollard et al., 2004b); (Berry & Haine, 2002); (Watkins & McAleer, 2002); (McMillan & Speight, 2001); (Haine & Berry, 2000)
Review	(Porru, 2015); (Knoepfel & Brabeck-Letmathe, 2012);(Killick, 2011); (Thompson, 2006)

Source: Author's own study based on (Scopus data, 2023).

Out of 87 publications, two books, three book chapters, two review publications and 80 articles containing the results of empirical research were awarded. Statistical methods were used in most of the publications. Four publications were of a review, in two publications a critical literature review was used as the main research method, and in 81 – a statistical method. The statistical methods used in the publications are shown in Figure 7.

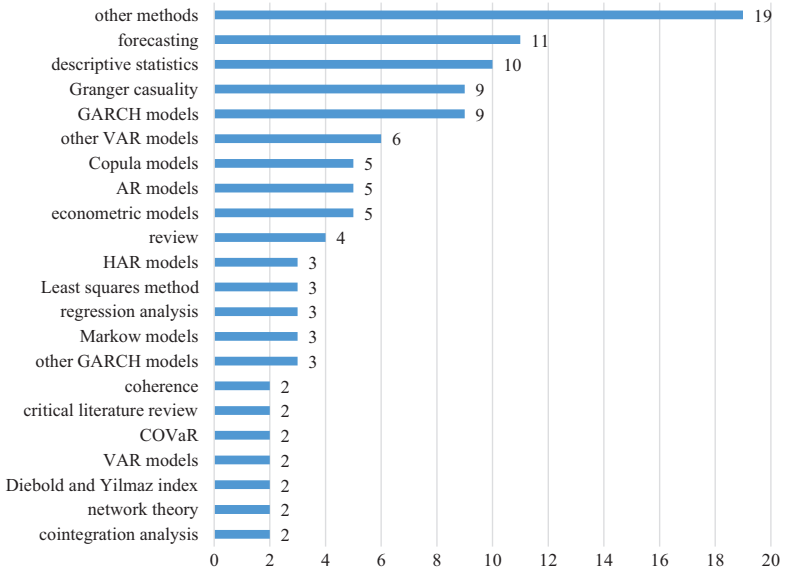

Figure 7. Statistical methods used in publications

Source: Author's own study based on (Scopus data, 2023).

In the largest number of publications (i.e. 11) methods related to forecasting were used. In a few cases, descriptive statistics (ten publications), issues related to causality in the Granger sense (nine publications) and GARCH models (eight publications) were used. Econometric models were used in most of the publications. Autoregressive models and Copula models were often used. Methods related to neural networks and valuation theory were also used in the publications. Some of the publications also used another GARCH models (three publications): HAR-GARCH, TGARCH, EGARCH and TVP-GARCH models. Other VAR-type models were also used (six publications), including TVP-VAR, TVP-SV-VAR and FCVAR models. Another methods were also used in the publications, including other models: error correction model, ARIMAX models, Copula-COVaR models, panel data model, HOM model, and other methods: Phillips multiple bubbles testing, structural breaks in full time-series, multifractal, VR Wright non-parametric coefficient of variance, risk measure GlueVar, correlations, valuation, Hill estimator and spectral analysis. The publications included a diverse research subject (Figure 8).

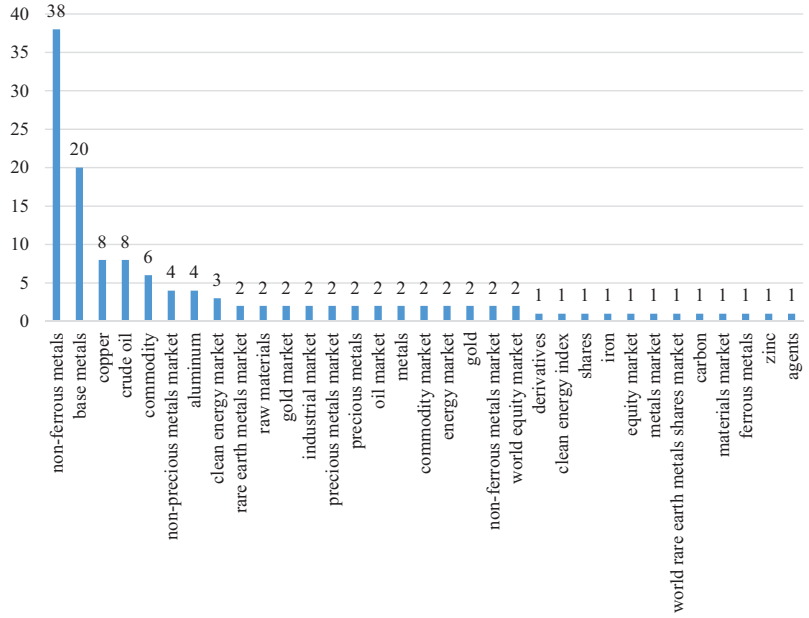

Figure 8. Research subject appearing in publications

Source: Author's own study based on (Scopus data, 2023).

Most often, the subject of the study specified by the authors were non-ferrous metals. It has been worded like this 38 times. In 20 publications, base metals were identified as the key theme. In these cases, therefore, a narrower wording was used in relation to the term "non-ferrous metals". In eight publications, the subject of the study was copper, i.e. a specific non-ferrous metal. In eight publications, crude oil was identified as the subject. Despite the fact that it is not a non-ferrous metal, it appears relatively often as a subject of research, due to the multitude of analyses of the properties of non-ferrous metals in the context of the properties of crude oil. Six times the subject of the study was referred to as commodity. Therefore, a broader term is used here in relation to non-ferrous metals. The non-precious metals market has been the subject of research in four publications. In four publications, the subject was aluminium, one of the non-ferrous metals. Publications also differed in terms of highlighted keywords (Figure 9, Figure 10).

The three most frequently used keywords directly related to the non-ferrous metals market were*:* "base metals", "non-ferrous metals" and "copper". The popularity of individual keywords has varied over the years. Between 2000 and 2017, keywords related to "non-ferrous metals" appeared less frequently, as fewer publications in this area were published. Topics related to the non-ferrous metals market began to be discussed more frequently in scientific papers after 2017. By 2014, all three of these keywords were used at comparable rates. In 2015, there was an increase in the use

of the term "base metals". After 2017, the three expressions mentioned began to be used more frequently. In those years, the term "base metals" was used the least. The term has gained a lot of popularity in 2023 when it has been used as many times as "non-ferrous metals". The phrase "non-ferrous metals" was most commonly used after 2019. The word "copper" was used the most times in 2019.

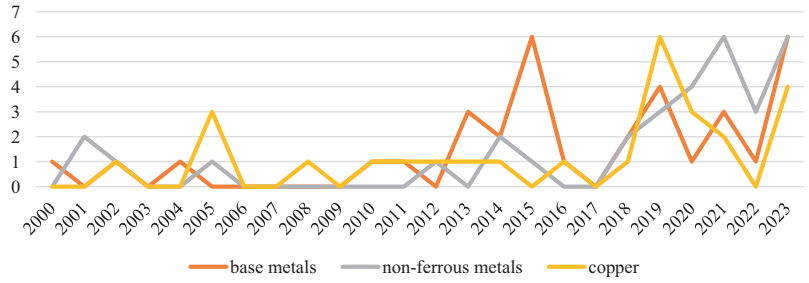

Figure 9. Keywords over the years

Source: Author's own study based on (Scopus data, 2023).

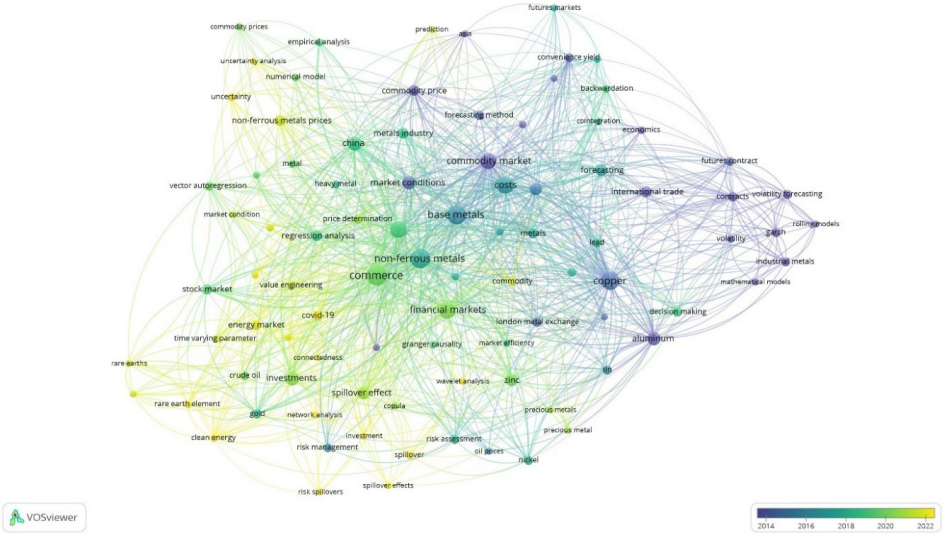

Figure 10. Keywords that appear in publications at least 3 times

Source: Author's own study based on (Scopus data, 2023).

Analysing keywords not only directly related to the non-ferrous metals market, but more broadly, the most frequently used keywords included: "commerce" – occurring 26 times, "non-ferrous metals" – occurring 25 times, "base metals" – used 24 times and "copper" – occurring 22 times. The term "non-ferrous metals" was used

more frequently in later years than "base metals". In recent years, more and more keywords include the following expressions: "price dynamics" and "non-ferrous metals prices". Publications on "aluminium" and "copper" were the earliest, but later they also began to describe the markets for other non-ferrous metals – "lead", "nickel", "tin", "gold", and "zinc". In recent years, more publications have been published with the phrase "precious metals" in their keywords. Analysing the changes occurring in the selection of keywords, one can see the impact of recent crises, such as the climate crisis, the COVID-19 pandemic or the war in Ukraine. During this time, the phrases "energy market", "clean energy", "prices" and "uncertainty" appeared more and more frequently among the keywords. This demonstrates the growing interest of researchers in issues related to renewable energy sources, prices volatility and uncertainty in the metals market as a result of crisis situations. The term "non-ferrous metals" is often combined with other keywords, notably the following: "commerce", "price dynamics", "financial market", as well as keywords indicating the methods used: "Copula models", "regression analysis", "uncertainty analysis", "prediction" and "forecasting", and "GARCH models".

Keywords can be divided into six clusters in terms of their co-occurrence. The first cluster is the most numerous and contains 19 keywords. They focus on issues related to non-ferrous metals, empirical analysis, regression analysis, prediction and the Chinese market. The second cluster consists of 18 keywords that deal with issues related to the commodity market, commodity prices, financial market phenomena, forecasting, issues related to base metals, including lead. The third cluster includes 17 keywords, focused on gold and the energy market, including clean energy. Cluster 4 consists of 15 keywords. Their topics include risk, externalities, as well as oil, tin and zinc. Cluster 5, with 14 elements, focuses on industrial metals, including copper and aluminium, forecasting, and volatility. Cluster 6, the least numerous, contains nine keywords in the field of time series analysis, Granger causality and market efficiency.

Discussion

Non-ferrous metals are important in many areas of the economy, and their prices are sensitive to crisis situations such as wars and regional conflicts, as well as changes in the political situation (Yang et al., 2023). Demand for non-ferrous metals is constantly growing, because with increasing wealth, technical and technological progress, both the demand from existing uses of these metals and this related to their new applications are increasing (Charpentier Poncelet et al., 2022). In recent years, issues related to non-ferrous metals may be gaining importance due to changes in the structure of demand and supply of these metals. Demand for metals has been increasing, due to, among other things, new applications for these metals, including their use in the production of electric cars or renewable energy sources (Mateus & Martins, 2021). On the other hand, the European supply of metals is decreasing,

partly due to the depletion of local primary resources and mine closures (Troll & Arndt, 2022). For example, a decrease in the supply of copper is forecast, with a simultaneous high demand for this metal, caused by, among others, the popularization of electric vehicles and the wider use of renewable energy sources (Galán-Gutiérrez & Martín-García, 2022). Recent crisis situations have also contributed to the increase in the demand for metals (Troll & Arndt, 2022). In addition, there has been increasing attention to raw material security in the European Union, submitting EU countries to try to limit imports of metals from outside member states (Regulation (EU) 2024/1252…, 2024). As a result, it is becoming increasingly difficult to ensure stable access to metals, which increases the importance of and interest in this topic.

Issues related to the market of non-ferrous metals are considered in the world literature. The popularity of this subject has been increasing in recent years, which may be related to the difficulties associated with obtaining these raw materials, as well as the volatility of their prices and the uncertainty on the non-ferrous metals market caused by crises. Despite the popularity of both non-ferrous metals and bibliometric analysis, there are no studies in the literature on bibliometric analysis of publications related to the market and investments in non-ferrous metals.

Conclusions

Most publications on the non-ferrous metals market in the years 2000–2023 were issued by N. Todorova, who published seven articles, as well as M. McAleer and C. Watkins, who published five articles each. The most frequently cited publications were N. Todorova (124 citations) and X. Zhu (103 citations).

The largest number of articles on the non-ferrous metals market was published in the journal *Resources Policy*, which published 28 articles on this issue. Most of the journals containing the articles were indexed in the Web of Science Journal Info, Scimago Journal & Country Rank and ABDC Journal Quality List. The Web of Science Journal Info indexed journals with 63 analysed articles, the Scimago Journal & Country Rank 68, while the ABDC Journal Quality List indexed journals with 59 analysed articles.

Forecasting methods, descriptive statistics, Granger's causality issues and GARCH models were most often used in the publications. The subject of the study was most often formulated as: non-ferrous metals, base metals or copper. The three most commonly used keywords were: base metals, non-ferrous metals and copper. The term "non-ferrous metals" was used more frequently in later years than base metals. In recent years, keywords have increasingly included the phrases: price dynamics and non-ferrous metals prices.

Based on the literature review, it can be concluded that among researchers dealing with the subject of the non-ferrous metals market and investments in these metals, there are few authors from Central and Eastern Europe, including Poland. This

translates into a small number of publications and citations from scientists in the region. As a result, the specificity of the non-ferrous metals market and investments in non-ferrous metals in Poland and other Central and Eastern European countries is not examined. Therefore, it is not known how changes in this market affect the economic situation of the countries of Central and Eastern Europe. In addition, the properties of non-ferrous metals are analysed primarily taking into account the properties of crude oil. It is also worth examining the properties of non-ferrous metals in the context of other raw materials, besides oil.

The conclusions contained in this article will be useful primarily to scientists. Thanks to the critical literature review, they will be able to get acquainted with the current state of knowledge in the area of the non-ferrous metals market, and on this basis assess the current state of knowledge in this area and plan further research directions. The results contained in this study may also be useful to enterprises and governments. These conclusions can help to better understand the changes taking place in the non-ferrous metals market. These results identify journals that are particularly worth looking at when seeking information on this market and investments in it. In addition, becoming familiar with the most commonly used methods for analysing this market can help improve public and business analyses and forecasts.

This article presents the current scientific achievements on the non-ferrous metals market and investments in non-ferrous metals, but it is not exhaustive. The limitation of this study is primarily the limitation of research to English-language literature and to items included in the Scopus database. In subsequent studies, it is worth conducting a bibliometric analysis of the literature available in databases other than Scopus. It would be important to extend the analyses to non-English language positions. Future research should also focus on and comparison of European, American and Asian literature on the non-ferrous metals market, as well as on comparing the description of individual metals markets in the literature. In addition, it will be valuable to compare the results obtained using keywords and restrictions set during the conducted research with the results obtained using other, close-meaning keywords. Other methods are also worth using, including the network analysis and machine learning models to better understand co-authorship and influential research centres. It is also worth using other bibliometric analysis methods in addition to PRISMA.

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