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Scale-Level Analysis of the Profitability and Export Performance of the Basic Metal Industry in Türkiye Using the Entropy-Weighted TOPSIS Method

(Türkiye'de Ana Metal Sanayiinin Karlılık ve İhracat Performanslarının Entropi Ağırlıklandırmalı TOPSIS Metodu Kullanılarak Ölçek Düzeyinde Analizi)

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Abstract

The manufacturing industry constitutes one of the most significant components of Türkiye's real economy. This sector plays a critical role in various economic indicators, including Gross National Product, welfare levels, employment, value-added generation, foreign trade, and tax revenues. Among these sectors, the basic metal industry stands out as a leading subsector, particularly distinguishing itself from others in terms of value-added, profitability, and export performance. In this study, the basic metal industry, as a subsector of Türkiye's manufacturing industry, is analyzed by classifying enterprises into micro, small, medium, and large-scale groups. The data were derived from financial statements (income statements and balance sheets) obtained from the Central Bank of the Republic of Türkiye's Real Sector Statistics. The dataset covers the period from 2009 to 2023; however, analyses for comparative purposes were conducted for the years 2009 and 2023. The data were analyzed using the Entropy-weighted TOPSIS method, with separate weighting applied for each year and enterprise size. Based on these weightings, profitability and export performance were calculated and ranked for the periods 2009 and 2023. The findings indicate that enterprise performance in 2023 is higher compared to 2009 and that performance improves progressively as firm size increases from micro to large-scale enterprises.

Keywords:
Basic metal industry, Entropy method, TOPSIS method

Article type:
Research

ÖZ

İmalat sanayi sektörleri, Türkiye reel ekonomisinin en önemli bileşenlerinden birini oluşturmaktadır. Bu sektörler; Gayri Safi Milli Hasıla, refah düzeyinin belirlenmesi, istihdam, katma değer yaratımı, dış ticaret, vergi gelirleri gibi birçok değişken açısından kritik bir rol oynamaktadır. Bu sektörler arasında ana metal sanayi, öncü alt sektörlerden biri olarak öne çıkmaktadır. Özellikle katma değer, kârlılık ve ihracat performansı açısından diğer sektörlerden ayrışmaktadır. Bu çalışmada, Türkiye imalat sanayinin bir alt sektörü olan ana metal sanayi; mikro, küçük, orta ve büyük ölçekli işletmeler ayrı ayrı gruplandırılarak analiz edilmektedir. Veriler, Türkiye Cumhuriyet Merkez Bankası Reel Sektör İstatistikleri kapsamında yer alan finansal tablolar (gelir tablosu ve bilanço) kullanılarak hesaplanmıştır. Veriler 2009-2023 yıllarını kapsamaktadır. Ancak, analizler karşılaştırma için 2009 ve 2023 yılları için yapılmıştır. Veriler, Entropi ile ağırlıklandırılmış TOPSIS yöntemi ile analiz edilmiştir. Her bir yıl ve her bir büyüklük için ayrı ayrı ağırlıklandırma yapılmıştır. Bu ağırlıklandırmalar bağlamında 2009 ve 2023 dönemleri için karlılık ve ihracat performansları hesaplanarak listelenmiştir. Elde edilen bulgular 2023 yılı işletme performanslarının 2009 yılına göre daha yüksek olduğu ve firma ölçeklerinin mikrodan büyük ölçeğe doğru yükseldikçe performanslarının arttığı şeklinde ortaya konulmuştur.

Anahtar Kelimeler:
Ana metal sanayii, Entropi metodu, TOPSIS yöntemi

Makale Türü:
Araştırma

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1. Introduction

The basic metal industry is one of the important sub-sectors of the manufacturing industry. It is a sector that encompasses the production and processing of base metals, primarily iron and steel, as well as aluminum and copper. The production of this sector is used as a key input in many final products of daily life, particularly in the automotive, white goods, defense, and construction sectors. The basic metal industry involves the production of primary iron and steel products and ferroalloys, the manufacturing of steel tubes, pipes, hollow profiles, and similar connection parts, the production of other products obtained during the initial processing of steel, the production of precious base metals, and other non-ferrous metals, as well as the stakeholders in the metal casting industry.

The production of basic metals is a heavy industry sector with high fixed costs and requires a lengthy process. From raw material procurement to melting, casting, and cutting, the process involves intensive labor and technology-supported automation. In 2023, the manufacturing industry sector accounted for 19.5% of the Gross Domestic Product (GDP), placing it among the top contributors (Turkstat, 2024). Similarly, the manufacturing industry sector, and specifically the basic metal industry sub-sector, is a key contributor to Türkiye's export performance. To sustain this performance, it is crucial to maintain and enhance competitive performance in international trade (Şit et al., 2017). The basic metal industry follows a trend parallel to the development process of the manufacturing industry sectors. The growth performance of these sectors also has a positive impact on overall economic growth (Eyüboğlu & Bayraktar, 2019). The sector's contribution to sustainable economic growth must be steadily increased. Within the total manufacturing industry, the basic metal industry is the second driving sector after motor vehicles, and it is a sector that requires careful consideration due to its sensitivity to internal and external factors affecting international trade, as well as its exchange rate sensitivity. Additionally, according to the classification based on Turkstat Nace Rev 2 codes, the sector is categorized as a medium-low technology-intensive industry (Akdoğan et al., 2019). The basic metal industry, located at a medium level on the labor-intensive-technology-intensive scale within the manufacturing industry and its sub-sectors, is significant both in terms of its potential to enhance value-added performance and its ability to absorb intermediate labor employment due to its labor-intensive nature. Therefore, improving the performance of companies operating in these sectors affects the trajectory of national income and per capita income.

A wide variety of variables and analysis methods have been developed to assess company performance. The variables and methods used in the analyses vary depending on the perspective from which the companies are being evaluated. Different queries can be made based on factors such as production and sales volumes, exports, and financial performance. The most commonly used methods for analyzing the financial performance of companies include TOPSIS, PROMETHEE, and Data Envelopment Analysis (DEA). In the study, the performance evaluation of companies operating in the basic metal industry sub-sector of the manufacturing industry was conducted based on scale. Using criteria commonly employed in the literature, the performance of the basic metal industry sector was analyzed according to its scale using the Entropy-weighted TOPSIS method, with data from 2009 to 2023.

The dataset used in this study covers the period from 2009 to 2023. This timeframe was selected because the sectoral balance sheets and income statements published by the Central Bank of the Republic of Türkiye (CBRT) encompass these years. However, since a comparative approach was preferred in the study's methodology, it was deemed more illustrative to conduct comparisons between the starting and ending periods rather than performing separate analyses for each year. In addition, to provide an overview of the period, supporting information has been summarized in the scale trends presented in Figure 1. Seven different variables were utilized in the selection of criteria. These variables represent profitability measures that have been highlighted in similar studies on sectoral and firm performance. Furthermore, an additional variable was included to assess foreign trade performance. The findings

obtained were interpreted within the conceptual framework of this study, and policy recommendations were provided.

It should be noted, however, that the structural transformation causes of the sectors, potential external influences, macroeconomic policies, exchange rates, interest rates, minimum wage policies, support provided to priority sectors in line with development plans, the impact and extent of other sectors directly or indirectly affecting the main metal industry, and whether the main metal industry is competitive, are beyond the primary scope of this study. Therefore, other determinants affecting the sector and firms at the scale level may be discussed in separate studies based on the perspective derived from this research. Generally, this study aims to answer the following research question: To what extent do profitability and export performance vary across firm size levels (micro, small, medium, and large-scale enterprises) in Türkiye's basic metal industry, one of the most important subsectors of the manufacturing sector.

2. Manufacturing Industry and Basic Metal Industry in Türkiye

Manufacturing industry sectors form the fundamental building blocks of the economy in Türkiye. These sectors, which directly impact areas such as production, employment, export, taxes, and added value, also cover significant aspects such as international technology transfer, capital accumulation, and competition.

According to the 2024 data from the World Steel Association (2025), the total global steel production is approximately 1.881 billion tons, with more than 1 billion tons of this production coming solely from China. India ranks second with about 150 million tons, followed by Japan with 85 million tons. Türkiye ranks among the top 10 countries with an annual production of 37 million tons. The leading countries in the global basic metal sector, both in terms of production and exports, are China, India, Japan, the USA, Russia, South Korea, Germany, Türkiye, Brazil, and Iran. However, approximately 25% of total global exports (427 million tons) are provided by China, while Japan, South Korea, Germany, Italy, Belgium, Russia, Türkiye, and Brazil also rank among the top exporters.

According to 2025 data, the Turkish economy, which reached a Gross Domestic Product (GDP) of approximately 1.59 trillion dollars, is significantly influenced by the manufacturing industry and the basic metal industry sectors. Tables 1 and 2 present data for the last five years on Türkiye's GDP, exports, imports, manufacturing industry exports and imports, and basic metal industry exports and imports. Along with the notable increase in GDP, there has also been a significant rise in export and import figures. One important point here is that the share of manufacturing industry sectors in exports is exceptionally high, at around 94%. It is also observed that the share of the basic metal industry within the manufacturing industry sectors has fluctuated between 9% and 13% during the same period (WB, 2025; Turkstat, 2024).

The same can be said for imports. In parallel with the increase in GDP over the past five years, there has also been a rise in imports. The share of manufacturing industry sectors in total imports is observed to be between 70% and 80%. Looking at the share of the basic metal industry sectors within the manufacturing industry sectors in terms of imports, it can be seen that this share has fluctuated between 17% and 23% (Turkstat, 2024).

Table 1. GDP and exports trend (2019-2025)

Years	GDP 000.000 $	Total Export 000.000 $	Export of Manufacturing Industry/Total Export (%)	Export of Basic Metal Industry/Export of Manufacturing Industry (%)
2019	761.006	180.832	94,68	9,86
2020	720.338	169.637	94,29	10,29
2021	819.865	225.214	94,49	13,58
2022	907.118	254.169	94,57	11,10
2023	1.118.250	255.627	94,24	9,22
2024	1.322.000	261.820	94,1	12,6
2025	1.596.000	273.400	94,3	12,7

Kaynak: WorldBank (2025). World Bank national accounts data, and OECD National Accounts data files, https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=OE-TR and Turkstat (2024). Foriegn Trade Statistics. https://data.tuik.gov.tr/Bulten/Index?p=Dis-Ticaret-Istatistikleri-Nisan-2024-53528.

However, interpreting foreign trade data solely based on nominal figures or only in proportional terms may lead to an incomplete assessment. Therefore, when examining the export figures previously given as ratios in nominal terms, it is observed that total exports have increased from approximately 180 billion dollars to around 273 billion dollars. Within this growth, the manufacturing industry sectors have also shown a similar upward trend, rising from about 170 billion dollars to 260 billion dollars over five years. Likewise, the export figures for the basic metal industry have increased from approximately 17 billion dollars to around 29 billion dollars. From the perspective of imports, it is observed that total imports have increased in parallel with the rise in national income. The total import figure, which was around 210 billion dollars in 2019, reached approximately 344 billion dollars by 2024 and 365 billion dollars in 2025. Similarly, the imports of the manufacturing industry sectors rose from 162 billion dollars to 300 billion dollars, while the share of the basic metal industry within this import volume increased from approximately 30 billion dollars in 2019 to around 62 billion dollars in 2025 (Turkstat, 2025).

Table 2. GDP and imports trend (2019-2023)

Years	GDP 000.000 $	Total Imports 000.000 $	Manufacturing Industry Imports / Total Imports	Imports of Primary Metals Industry / Imports of Manufacturing Industry
2019	761.006	210.345	77,08	17,99
2020	720.338	219.516	81,91	23,63
2021	819.865	271.425	75,88	17,48
2022	907.118	363.710	71,79	21,68
2023	1.118.250	361.966	80,69	21,23
2024	1.322.000	344.000	81,4	21,01
2025	1.596.000	365.400	81,8	22,20

Kaynak: WorldBank (2025). World Bank national accounts data, and OECD National Accounts data files, https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=OE-TR and Turkstat (2024). Foriegn trade statistics. https://data.tuik.gov.tr/Bulten/Index?p=Dis-Ticaret-Istatistikleri-Nisan-2024-53528.

One of the most striking aspects of the figures presented above is that while both exports and imports follow a trajectory parallel to national income, there is also a significant trade deficit in total foreign

trade, the manufacturing industry as a whole, and the basic metal industry sector. This issue raises an important point that could spark discussions on labor exploitation in Türkiye's manufacturing industry

3. Literature Review

Acar and Sarıyer (2021) conducted a performance analysis using the AHP-weighted TOPSIS method based on the 2017 financial indicators of 17 basic metal industry companies traded on BIST. By comparing the obtained data and rankings with the companies' year-end closing prices, they demonstrated that the relationship between the variables exhibited a parallel trend.

Kılıç (2025) conducted an efficiency analysis using the Data Envelopment Analysis (DEA) method based on the 2018–2022 data for the BIST Basic Metal Industry. By utilizing financial indicators, the study assessed firms' efficiency levels. The ranking based on CCR-I super-efficiency scores revealed the efficiency levels of the examined firms.

Gönüllü (2022) analyzed the performance of companies in the BIST Basic Metal Index during the pandemic period. Using data from balance sheets and income statements, the study applied the entropy method for criteria weighting and the MARCOS method for ranking. The findings indicate that companies maintaining operational efficiency during the pandemic achieved positive performance, while others experienced negative outcomes.

Güçlü and Muzac (2024) analyzed the four largest companies in the iron and steel sector using data from the 2017–2021 period. They applied the MULTIMOORA method for performance analysis. The study evaluated the performance of each company separately for each year and provided recommendations regarding the methodology.

Yayar and Özhuy (2021) conducted a performance measurement using Data Envelopment Analysis (DEA) for 20 basic metal industry companies traded on BIST, based on 2021 data. The analysis used net total assets, equity, number of employees, net sales, exports, and gross value added as criteria. Both CCR and BCC models were applied, revealing that 9 firms were found to be efficient under the CCR model, 11 under the BCC model, and 11 based on scale efficiency.

Karagül and Büyük (2024) conducted a concentration analysis based on data from firms operating in the manufacturing industry's iron-steel basic metal, non-iron-steel basic metal, and metal goods sectors. The study utilized data from the 2013–2020 period for the N-firm concentration ratio and the Linda index. The findings indicated that these sectors exhibit a competitive, low-concentration oligopolistic structure.

Çolak (2023) conducted an analysis to measure the performance of companies listed on the BIST Basic Metal Index, using variables related to liquidity, profitability, financial structure, and operations for the years 2017-2018. The performance analysis, conducted using the TOPSIS method, resulted in a ranking of the companies in the sector based on these variables.

Bakırcı, Shiraz, and Sattary (2014) conducted a performance analysis using data from publicly traded companies in the iron and steel sector between 2009 and 2011. The study applied the Data Envelopment Analysis (DEA) method for the analysis. For relative efficiency measurement, super-efficiency and TOPSIS methods were used, and a comparative evaluation was made based on the results for the specified period.

Çanakçıoğlu (2020) conducted a performance analysis based on data from 17 companies listed on the BIST Basic Metal Index between 2013 and 2018. Thirteen variables were used as criteria, with the entropy method applied to determine the criteria weights, and the WASPAS method used for performance analysis. A separate ranking was made for each year, and a comparative evaluation was carried out.

4. Data, Method and Findings

In the study, the basic metal industry sector was selected as a sub-sector of the manufacturing industry. The data used were obtained from the income statement and balance sheet items published by the Central Bank of the Republic of Türkiye (CBRT) under the real sector data. Among the performance indicators commonly used in the literature, profitability ratios (sales profitability and investment profitability) were preferred, and the export performance indicator was also included CBRT, 2025).

The sales profitability indicators are as follows;

Gross Profit Margin = Gross Sales Profit/Net Sales
Operating Profit Margin = Earnings Before Interest and Taxes/Net Sales
Period Profit Margin = Period Profit/Net Sales
Net Profit Margin = Net Profit/Net Sales

The investment profitability indicators are;

Return on Assets (ROA) = Net Income/Total Assets
Return on Equity (ROE) = Net Profit/Equity

For the export performance indicator is;

Export Performance = Foreign Sales/Gross Sales

The results obtained form the criteria variables of the decision matrix. The alternative variables of the decision matrix consist of the scales of firms operating in the basic metal industry. According to the Central Bank of Türkiye, based on criteria such as turnover, employment contribution, and others, the number of firms classified and included in the measurement as of 2023 is as follows: 2,077 micro-sized firms, 1,027 small-sized firms, 424 medium-sized firms, and 200 large-sized firms, totaling 3,908 firms. Between 2009 and 2023, the number of micro, small, and medium-sized firms increased by approximately 100%, while the number of large firms grew by about 25% (CBRT, 2025).

4.1. Entropy Method

In multi-criteria decision-making methods, different techniques can be preferred depending on the nature of the study. For objective assessments, methods such as the AHP method are often used to determine the weights of criteria by utilizing expert opinions, while relatively objective methods are preferred for weighting data compiled from secondary sources. The entropy method is one of these. The entropy method is a widely used approach to measure the distribution of values (Zhu et al., 2020). As one of the objective weighting tools, the entropy method helps in determining the importance weights of criteria by relying solely on data, thus preventing personal judgments and opinions from influencing the model (Ömürbek & Kişi, 2019). In practice, after specific operations for each criterion, a weight value is assigned based on its relevance to all variables. As a result of this ratio, the influence of each variable on the outcome depends on its weight in the selection of alternatives. Therefore, the entropy method is emphasized as a useful application for making choices or ranking between criteria.

1st Step: Formation of the Decision Matrix

$$\mathrm{F} = f(Xij)mxn = \begin{vmatrix} f_{11} & f_{12} & f_{1n} \\ f_{21} & f_{22} & f_{2n} \\ f_{m1} & f_{m2} & f_{mn} \end{vmatrix}$$

i= 1,2,…m (alternatives) (micro scale, small scale, medium scale, large scale firms)

j= 1,2,…n (criteria) (Gross profit margin, Operating profit margin, Period profit margin, Net profit margin, Return on Assets (ROA), Return on Equity, Exports/Gross sales)

Table 3. Decision matrix (F) (2009 and 2023)

Year	Scale	Gross Profit Margin=Gross Sales Profit/Net Sales	Operating Profit Margin=Earnings Before Interest and Taxes/Net Sales	Period Profit Margin=Period Profit/Net Sales	Net Profit Margin=Net Profit/Net Sales	Return on Assets (ROA)=Net Income/Total Assets	Return on Equity (ROE)=Net Profit/Equity	Export Performance=Foreign Sales/Gross Sales
2009	Large	0,04216	-0,00507	-0,02093	-0,02413	-0,0222	-0,04631	0,397958
2009	Medium	0,11340	0,05072	0,030378	0,03037	0,02291	0,05252	0,173022
2009	Small	0,11672	0,03154	0,014756	0,00738	0,00647	0,018031	0,091202
2009	Micro	0,09682	-0,02413	0,003326	-0,0037	-0,0004	-0,00067	0,039835
2023	Large	0,14901	0,10893	0,064965	0,05333	0,06723	0,175362	0,258715
2023	Medium	0,12408	0,07227	0,067264	0,06726	0,07957	0,212251	0,212392
2023	Small	0,11098	0,05565	0,042483	0,03126	0,04175	0,150515	0,096867
2023	Micro	0,13486	0,02010	0,027526	0,01316	0,00661	0,016013	0,088042

2nd Step: Normalized Decision Matrix

The normalization of the decision matrix is done by dividing each matrix cell by the sum of its respective column. This ensures that the values in each column are scaled relative to the total of that column, allowing for a comparison of the criteria across different alternatives.

$$e\text{ij} = \frac{f\ ij}{\sum_{i=1}^{m} fij}$$

Table 4. Normalized decision matrix (eij Values) (2009 and 2023)

Year	Scale	Gross Profit Margin=Gross Sales Profit/Net Sales	Operating Profit Margin=Earnings Before Interest and Taxes/Net Sales	Period Profit Margin=Period Profit/Net Sales	Net Profit Margin=Net Profit/Net Sales	Return on Assets (ROA)=Net Income/Total Assets	Return on Equity (ROE)=Net Profit/Equity	Export Performance=Foreign Sales/Gross Sales
2009	Large	0,21732	-0,07846	-0,52490	-0,60832	-0,682810	-0,64043	0,89386
2009	Medium	0,58453	0,78497	0,761927	0,765881	0,702894	0,726344	0,38863
2009	Small	0,60166	0,48806	0,370106	0,186186	0,198710	0,249363	0,20485
2009	Micro	0,49908	-0,37342	0,083416	-0,093248	-0,01489	-0,00926	0,08947
2023	Large	0,57099	0,759110	0,610940	0,577840	0,598017	0,558145	0,71982
2023	Medium	0,47545	0,503679	0,632562	0,728728	0,707814	0,675556	0,59093
2023	Small	0,42528	0,387847	0,399512	0,338716	0,371371	0,479061	0,26951
2023	Micro	0,51676	0,140118	0,258856	0,142573	0,058799	0,050964	0,24495

3rd Step: Obtaining Entropy Values

At this stage, the entropy values for each criterion are calculated. The calculation involves taking the logarithm of each value in the normalized decision matrix, multiplying it by the respective value, and then dividing the sum of the obtained values for each column by the logarithm of the alternatives. This process helps to determine the entropy for each criterion, reflecting the degree of uncertainty or dispersion in the data for that criterion.

$$Ej = -\frac{\sum_{i=1}^{m} eij\ \ \ln(eij)}{\ln(m)}$$

Entropy weights were computed individually for each year spanning 2009 to 2023, as well as for each enterprise size category, namely large, medium, small, and micro firms.

Table 5. Entropy values (Ej Values)

Year	Gross Profit Margin=Gross Sales Profit/Net Sales	Operating Profit Margin=Earnings Before Interest and Taxes/Net Sales	Period Profit Margin=Period Profit/Net Sales	Net Profit Margin=Net Profit/Net Sales	Return on Assets (ROA)=Net Income/Total Assets	Return on Equity (ROE)=Net Profit/Equity	Export Performance=Foreign Sales/Gross Sales
2009	0,129228	0,139614	0,138816	0,143744	0,15164	0,150393	0,146564
2010	0,129696	0,145615	0,148209	0,132628	0,143916	0,146782	0,153152
2011	0,116346	0,135306	0,176108	0,176322	0,135821	0,125838	0,134259
2012	0,132607	0,14069	0,151518	0,133929	0,148657	0,146904	0,145695
2013	0,127267	0,146299	0,139826	0,148032	0,145227	0,150285	0,143065
2014	0,13527	0,136693	0,135865	0,135256	0,153103	0,154725	0,149088
2015	0,127526	0,129256	0,148786	0,15446	0,14817	0,151432	0,140371
2016	0,125743	0,126775	0,165451	0,17039	0,137024	0,136909	0,137709
2017	0,129076	0,143267	0,13716	0,139526	0,159332	0,155918	0,135721
2018	0,121793	0,134535	0,144681	0,142457	0,161168	0,1611	0,134266
2019	0,130877	0,136267	0,144728	0,142219	0,152376	0,152055	0,141477
2020	0,133116	0,139412	0,137662	0,14285	0,153733	0,152083	0,141145
2021	0,124736	0,144754	0,137411	0,153114	0,155777	0,151781	0,132427
2022	0,134895	0,142957	0,138293	0,139702	0,152019	0,149207	0,142926
2023	0,133632	0,144008	0,137675	0,144295	0,149934	0,149081	0,141375

4th Step: Obtaining the Importance Weights (entropy values) of Each Criterion

In the fourth stage, the entropy values obtained in the previous step are subtracted from 1 (1-Ej). Then, the ratio of these values to the row sum of the (1 - Ej) values is calculated, resulting in the weight values (wj). This step allows for determining the relative importance of each criterion by adjusting the entropy values to reflect their significance in the decision-making process.

$$wj = \frac{1 - \mathrm{Ej}}{\sum_{j=1}^{n}(1 - Ej)}$$

4.2. TOPSIS Method

The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method was introduced by Chin-Lai Hwang and Kwangsun Yoon in 1981 and later developed with additional improvements. It is a weighting method used for ranking alternatives based on predefined criteria and their respective weight levels. The method calculates the Euclidean distance between each alternative and the ideal and negative ideal solutions. By comparing these distances, a preference order is established (Güler & Polatgil, 2023).

The steps of the TOPSIS method are as follows;

Creation of the Decision Matrix: This is a matrix that shows the variables subject to analysis and the criteria by which these variables will be analyzed. The decision matrix represents the relationship between alternatives and the criteria, with each element reflecting the performance of each alternative according to the respective criteria.

Normalized Decision Matrix: This is the weighting process used to calculate the contribution of each variable within the total, determined by dividing each cell value by the sum of the squares of the cell

values. This normalization step ensures that the values are scaled appropriately for comparison, eliminating the influence of differing units across criteria.

Entropy-weighted Normalized Decision Matrix: This is the stage where the importance weights of each variable are applied to their respective impact within the total, incorporating the effect of each variable into the process. It is referred to as the V matrix. In this step, the entropy method is used to determine the weights of the variables based on their distribution and significance in the decision-making process.

Determination of Positive and Negative Ideal Solution Values: The ideal solution values are obtained by calculating the minimum and maximum values for each column. The positive ideal solution is represented by the maximum values for each criterion, while the negative ideal solution is represented by the minimum values. In this step, any criterion that reflects negativity (such as costs or undesirable attributes) should be treated with its minimum value as part of the negative ideal solution. This helps to define the best (ideal) and worst (negative ideal) possible outcomes for each alternative.

Calculation of Ideal Solution Distances: This is the stage where the values in the decision matrix are processed with the ideal solution (A*) and negative ideal solution (A-) to estimate the proximity and distance to the ideal solutions. The distances are represented by S* (distance to the positive ideal solution) and S- (distance to the negative ideal solution). These values indicate how close or far each alternative is from the best (ideal) and worst (negative ideal) possible solutions.

The final step involves calculating the relative closeness to the ideal solution (Ci*) using the S* and S- values, followed by ranking the alternatives based on the resulting values. The Ci* value lies between 0 and 1, where values closer to 0 indicate lower performance, while values closer to 1 represent higher performance. This relative closeness value is used to rank the alternatives, with the highest Ci* value representing the most preferable alternative.

1st Step: Decision Matrix

$$\mathrm{F} = f(Xij)mxn = \begin{vmatrix} f_{11} & f_{12} & f_{1n} \\ f_{21} & f_{22} & f_{2n} \\ f_{m1} & f_{m2} & f_{mn} \end{vmatrix}$$

i= 1,2,…m (alternatives) (micro scale, small scale, medium scale, large scale firms)

j= 1,2,…n (criteria) (Gross profit margin, Operating profit margin, Period profit margin, Net profit margin, Return on Assets (ROA), Return on Equity, Exports/Gross sales)

Table 6. Decision matrix (F Values) (2009 and 2023)

Year	Scale	Gross Profit Margin=Gross Sales Profit/Net Sales	Operating Profit Margin=Earnings Before Interest and Taxes/Net Sales	Period Profit Margin=Period Profit/Net Sales	Net Profit Margin=Net Profit/Net Sales	Return on Assets (ROA)=Net Income/Total Assets	Return on Equity (ROE)=Net Profit/Equity	Export Performance=Foreign Sales/Gross Sales
2009	Large	0,04216	-0,00507	-0,02093	-0,02413	-0,0222	-0,04631	0,397958
2009	Medium	0,11340	0,05072	0,030378	0,03037	0,02291	0,05252	0,173022
2009	Small	0,11672	0,03154	0,014756	0,00738	0,00647	0,018031	0,091202
2009	Micro	0,09682	-0,02413	0,003326	-0,0037	-0,0004	-0,00067	0,039835
2023	Large	0,14901	0,10893	0,064965	0,05333	0,06723	0,175362	0,258715
2023	Medium	0,12408	0,07227	0,067264	0,06726	0,07957	0,212251	0,212392
2023	Small	0,11098	0,05565	0,042483	0,03126	0,04175	0,150515	0,096867
2023	Micro	0,13486	0,02010	0,027526	0,01316	0,00661	0,016013	0,088042

2nd Step: Normalized Decision Matrix

The normalized decision matrix is obtained by dividing each cell value by the square root of the sum of the squares of the values in that column. This process scales the values of each criterion so that they are comparable, regardless of their original units, enabling a more consistent and objective analysis.

$$rij = \frac{\text{Xij}}{\sqrt{\sum_{i=1}^{m}(x^2\text{ij})}}$$

Table 7. Normalized decision matrix (eij Values) (2009 and 2023)

Year	Scale	Gross Profit Margin=Gross Sales Profit/Net Sales	Operating Profit Margin=Earnings Before Interest and Taxes/Net Sales	Period Profit Margin=Period Profit/Net Sales	Net Profit Margin=Net Profit/Net Sales	Return on Assets (ROA)=Net Income/Total Assets	Return on Equity (ROE)=Net Profit/Equity	Export Performance=Foreign Sales/Gross Sales
2009	Large	0,21732	-0,07846	-0,52490	-0,60832	-0,682810	-0,64043	0,89386
2009	Medium	0,58453	0,78497	0,761927	0,765881	0,702894	0,726344	0,38863
2009	Small	0,60166	0,48806	0,370106	0,186186	0,198710	0,249363	0,20485
2009	Micro	0,49908	-0,37342	0,083416	-0,093248	-0,01489	-0,00926	0,08947
2023	Large	0,57099	0,759110	0,610940	0,577840	0,598017	0,558145	0,71982
2023	Medium	0,47545	0,503679	0,632562	0,728728	0,707814	0,675556	0,59093
2023	Small	0,42528	0,387847	0,399512	0,338716	0,371371	0,479061	0,26951
2023	Micro	0,51676	0,140118	0,258856	0,142573	0,058799	0,050964	0,24495

3rd Step: Normalized Decision Matrix Weighted by Entropy Values

In this step, the decision matrix is obtained by processing the normalized decision matrix with the criterion weightings calculated using the entropy method, according to the relevant formula. The matrix is obtained by multiplying each criterion's weight by the cell values of the alternatives in each column. The resulting matrix is shown below. The importance weights of the decision criteria are given by

$$v\ ij\ = wj\ .\ r\ ij$$

and the sum of the criterion weights is

$$\sum_{j=1}^{n} w\ j = 1$$

Table 8. Normalized decision matrix weighted by entropy values (V Matrix) (2009 and 2023)

Year	Scale	Gross Profit Margin=Gross Sales Profit/Net Sales	Operating Profit Margin=Earnings Before Interest and Taxes/Net Sales	Period Profit Margin=Period Profit/Net Sales	Net Profit Margin=Net Profit/Net Sales	Return on Assets (ROA)=Net Income/Total Assets	Return on Equity (ROE)=Net Profit/Equity	Export Performance=Foreign Sales/Gross Sales
2009	Large	0,02808	-0,01095	-0,07286	-0,08744	-0,10354	-0,09631	0,13100
2009	Medium	0,07553	0,109593	0,105767	0,110090	0,106587	0,109237	0,05695
2009	Small	0,07775	0,068141	0,051376	0,026763	0,030132	0,037502	0,03002
2009	Micro	0,06449	-0,05213	0,011579	-0,01340	-0,00225	-0,00139	0,01311
2023	Large	0,07630	0,109317	0,084111	0,083379	0,089663	0,083208	0,10176
2023	Medium	0,06353	0,072533	0,087088	0,105151	0,106125	0,100712	0,08354
2023	Small	0,05683	0,055853	0,055002	0,048874	0,055681	0,071418	0,03810
2023	Micro	0,06905	0,020178	0,035638	0,020572	0,008816	0,007597	0,03463

4th Step: Positive Ideal Solution (A*) and Negative Ideal Solution (A⁻) Values

Ideal solution values are determined by calculating the minimum and maximum values for each criterion column. The positive ideal solution consists of the maximum values for each criterion, representing the best possible outcome for each criterion. Similarly, the negative ideal solution consists of the minimum values for each criterion, representing the worst possible outcome for each criterion.

Positive ideal solution (max values);

$$A^+ = (v_1^+, v_2^+ , \dots \dots . v_n^+)$$

Negative ideal solution (min values);

$$A^- = (v_1^-, v_2^- , \dots \dots . v_n^-)$$

Table 9. Ideal solution values

		Gross Profit Margin=Gross Sales Profit/Net Sales	Operating Profit Margin=Earnings Before Interest and Taxes/Net Sales	Period Profit Margin=Period Profit/Net Sales	Net Profit Margin=Net Profit/Net Sales	Return on Assets (ROA)=Net Income/Total Assets	Return on Equity (ROE)=Net Profit/Equity	Export Performance=Foreign Sales/Gross Sales
2009	**A* (Max)**	0,07775	0,10959	0,10576	0,11009	0,10650	0,10923	0,13100
2009	**A- (Min)**	0,02808	-0,05213	-0,07286	-0,08744	-0,10354	-0,09631	0,01310
2023	**A* (Max)**	0,07630	0,10930	0,08708	0,10515	0,106120	0,10071	0,10176
2023	**A- (Min)**	0,05683	0,02017	0,03563	0,02057	0,00881	0,00759	0,03463

5th Step: Calculation of Distance from Ideal Solution Values

Distance from the positive ideal solution;

$$D_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2}$$

Distance from the negative ideal solution;

$$D_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}$$

Table 10. Si* and Si- values

Year	Scale	Si*	Si-	Year	Scale	Si*	Si-
2009	Large	0,7922	0,1248	**2023**	Large	0,1701	0,1771
2009	Medium	0,0471	0,4332	**2023**	Medium	0,2048	0,1819
2009	Small	0,4087	0,2854	**2023**	Small	0,3461	0,0934
2009	Micro	0,6117	0,1822	**2023**	Micro	0,4686	0,0122

6th Step: Calculation of Relative Closeness to the Ideal Solution

For each alternative, the similarity to the ideal solution is calculated as follows;

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-}$$

Table 11. Relative closeness of ideal solution

Year	Scale	Ci*	Year	Scale	Ci*
2009	Large	0,1361	**2023**	Large	0,5100
2009	Medium	0,9018	**2023**	Medium	0,4704
2009	Small	0,4111	**2023**	Small	0,2125
2009	Micro	0,2295	**2023**	Micro	0,0254

7th Step: Ranking of Alternatives

The results presented in Table 11, which report the relative closeness to the ideal solution (Ci*) obtained through the TOPSIS method, reveal a significant structural transformation across firm size groups between 2009 and 2023. Since higher Ci* values indicate better performance, the findings clearly demonstrate a shift in the relative efficiency of different scales.

In 2009, medium-sized enterprises exhibited the highest performance level, with a Ci* value of 0,90183, significantly outperforming all other groups. Small-scale firms followed with a moderate score of 0,41117, while micro enterprises (0,22952) and large-scale firms (0,13617) lagged behind. This distribution suggests that, at the beginning of the period, medium-sized firms constituted the most efficient and competitive segment within the sector. By contrast, the 2023 results indicate a notable reversal in this structure. Large-scale firms emerged as the leading group with a Ci* value of 0,51000, closely followed by medium-sized enterprises at 0.47043. Meanwhile, small-scale firms experienced a decline in performance (0,21253), and micro enterprises dropped to a critically low level (0,02542). This shift highlights a growing divergence between firm sizes, with smaller enterprises losing relative competitiveness over time.

Overall, the comparison between 2009 and 2023 suggests a clear transition from a structure dominated by medium-sized firms to one increasingly led by large-scale enterprises. This transformation points to the strengthening of scale economies and a rising concentration within the sector. In this context, the findings are likely to be consistent with an increase in market concentration as measured by indicators such as the Herfindahl-Hirschman Index. From a policy perspective, while large firms appear to benefit from efficiency and scale advantages, the declining performance of small and micro enterprises indicates a need for targeted support mechanisms, particularly in terms of access to finance, technology, and export markets.

Normalized Export Performance by Years

The performance of the basic metal industry sub-sector over the period 2009-2023 can be evaluated through graphical analysis within the framework of the selected criteria. In this context, the annual values obtained for each sector were transformed into the 0-1 range using the min-max normalization method. In this transformation, a value of 0 represents the lowest performance of the sector during the examined period, while a value of 1 indicates the highest level of performance. Accordingly, the year in which a sector exhibits its best performance is represented by the value 1, whereas the period with the weakest performance is indicated by the value closest to 0.

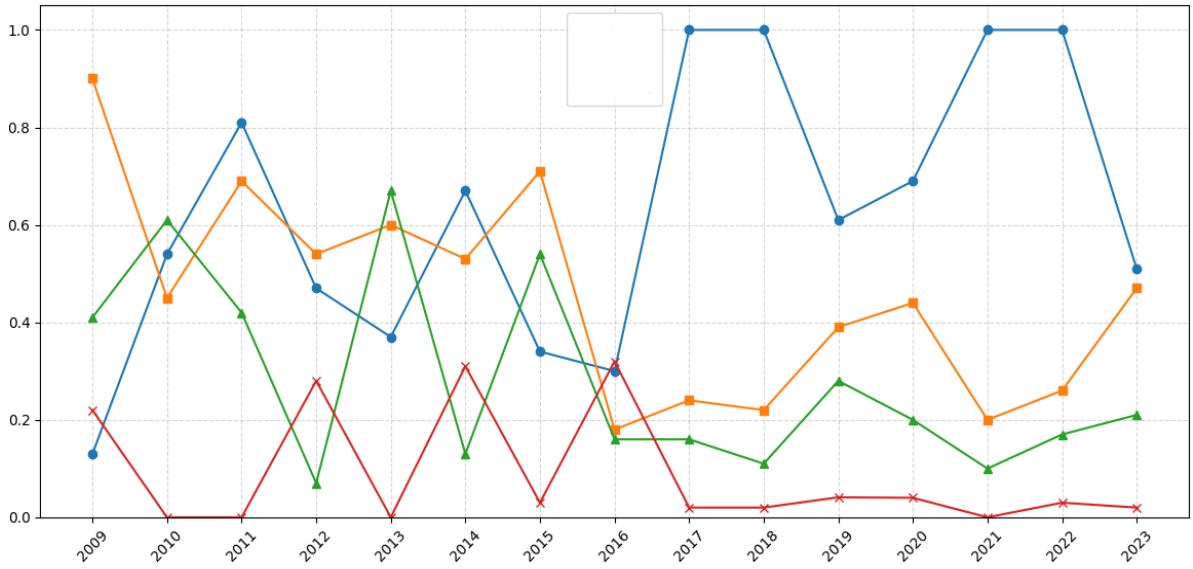

Figure 1. Normalized export performance in the period of 2009-2023

The large-scale firms, represented by the blue trend line, appear to have achieved performance levels very close to the ideal solution (Ci∗=1Ci^* = 1Ci∗=1) in 2011 and during the 2017-2022 period. In contrast, their performance can be considered moderate in 2009, 2012–2016, and 2023. Overall, although the trend exhibits a fluctuating pattern over time, a notable strengthening has been observed particularly after 2017. The performance trend of medium-scale firms, illustrated by the orange trend line, indicates relatively high performance levels (approximately between 0,5 and 0,7) in 2009 and throughout the 2011-2015 period. However, a significant decline is evident during the 2016-2022 period, with performance values falling to the range of 0,18-0,26. In this context, it can be argued that medium-scale firms have been unable to sustain their earlier performance levels and have exhibited a weakening trend. For small-scale firms, represented by the green trend line, low performance and instability are the most prominent characteristics. Although the highest performance level was recorded in 2013 with a value of 0,67, performance in other years generally fluctuates between 0,1 and 0,5. This suggests that small-scale firms display a volatile and inconsistent performance pattern within the sector. Finally, micro-scale firms, shown by the red trend line, demonstrate consistently low performance, typically ranging between 0 and 0,3. Although short-term increases are observed in 2012, 2014, and 2016, these improvements are not sustained over time. Overall, micro-scale firms remain considerably distant from the ideal performance level.

5. Evaluation and Conclusion

This study analyses the profitability and export performance of firms operating in the Turkish basic metal industry by employing the entropy-weighted TOPSIS method over the period 2009–2023, with a particular focus on scale-based differences. By utilizing Central Bank of the Republic of Türkiye real sector data and classifying firms into micro, small, medium, and large-scale groups, the study provides a comprehensive and comparative evaluation of structural transformation within the sector.

The empirical findings reveal a significant shift in performance dynamics across firm sizes over time. In 2009, medium-sized enterprises exhibited the highest performance levels, indicating that this group constituted the most efficient and competitive segment of the sector. However, by 2023, large-scale enterprises emerged as the leading group, surpassing all other firm sizes in terms of relative closeness to the ideal solution. This transformation suggests a structural transition from a medium-scale-driven performance structure to one increasingly dominated by large-scale firms. Another important finding is the substantial decline in the relative performance of small and micro-scale enterprises. While small firms maintain a moderate position, micro enterprises exhibit a critically low performance level in 2023.

This divergence indicates that the gap between firm sizes has widened over time, pointing to an increasing concentration of performance and competitiveness in larger firms. In this context, the results imply that economies of scale have become more pronounced in the Turkish basic metal industry, enabling large firms to achieve higher efficiency, profitability, and export capacity. Furthermore, the findings suggest that the observed structural transformation may be associated with increasing market concentration, which could be further supported by concentration measures such as the Herfindahl-Hirschman Index. The dominance of large firms, combined with the weakening position of smaller enterprises, indicates a shift toward a more oligopolistic market structure.

From a policy perspective, while the rise of large-scale firms may contribute positively to overall sectoral efficiency and export performance, the declining competitiveness of small and micro enterprises highlights the need for targeted policy interventions. In particular, improving access to finance, enhancing technological capabilities, and facilitating integration into export markets are crucial for strengthening the performance of smaller firms and ensuring a more balanced and sustainable industrial structure. Finally, this study contributes to the literature by offering a scale-based performance analysis using objective weighting through the entropy method and a comprehensive dataset covering a broad range of firms. However, future research may extend this analysis by incorporating panel data techniques, alternative multi-criteria decision-making methods, or sectoral comparisons to further validate and deepen the findings.

Author Contributions

The author solely contributed to all parts of the study.

Conflict of Interest Statement

The author declares that there is no conflict of interest.

Ethical Approval Statement

Academic and scientific ethical principles were followed in this study. Ethical committee approval was not required.

Use of Artificial Intelligence Tools

The author(s) did not use any artificial intelligence tools during the preparation of this study.

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