SCIENTIFIC OASIS

International Journal of Economic Sciences

Journal homepage: www.ijes-journal.org
eISSN: 1804-9796

Strategic Challenges and Opportunities for the Czech Steel Industry: A Path Toward Sustainable Competitiveness

Eduard Hromada[1], Klára Čermáková[1,*], Božena Kadeřábková[1], Lucie Kureková[1], Martina Krásnická[1]

[1] Department of Economics and Management, CEVRO University, Prague, Czech Republic

ARTICLE INFO

Article history:
Received 9 July 2025
Received in revised form 19 August 2025
Accepted 7 September 2025
Available online 11 September 2025

Keywords:
Czech steel industry; Decarbonization; Modernization; Global trade; European Green Deal; Energy efficiency; Product innovation; Competitiveness.

ABSTRACT

The Czech steel industry is a vital contributor to the national economy, supplying key sectors such as automotive, construction, and energy. However, it faces significant challenges, including global overproduction, high energy costs, decarbonization requirements, and declining demand in major markets. This article examines the systemic risks affecting the industry's competitiveness from 2008 to 2023, with a focus on global trade dynamics, EU environmental regulations, and workforce issues. Despite these pressures, the sector has demonstrated resilience. The study proposes a strategic approach centered on technological modernization, product diversification, policy collaboration, and workforce upskilling to ensure long-term sustainability and competitiveness in a rapidly evolving market.

1. Introduction

1.1 The Strategic Role of the Steel Industry in the Czech Economy

Steel production has been a cornerstone of Czech industrial development for decades, with a strong historical foundation rooted in the heavy industry traditions of regions such as Moravia and the Silesian part of the country. As a fundamental component of industrial production, steel serves as a critical input for key sectors of the Czech economy, including the automotive industry, construction, machinery manufacturing, and energy systems. The importance of steel transcends its direct contribution to GDP and employment; it also underpins downstream industries, creating significant multiplier effects within the broader economy. The steel industry not only secures jobs in steel production but also impacts numerous industries reliant on steel as a primary resource, from building materials to high-tech engineering components.

The Czech Republic has consistently positioned itself as a competitive player in the global and European steel markets. However, despite its strategic importance, the sector faces challenges that

* *Corresponding author.*
E-mail address: klara.cermakova@cevro.cz

https://doi.org/10.31181/ijes1412025207

test its resilience and long-term sustainability. These challenges demand a critical analysis of the systemic risks facing the industry, as well as the development of innovative strategies to retain its competitive edge in an increasingly volatile and regulated market.

1.2 The Changing Global Landscape and Challenges for Czech Steel

The past decade has witnessed a series of fundamental changes in the global steel industry, driven largely by economic cycles, overcapacity, and geopolitical developments. Between 2008 and 2023, the global steel sector encountered significant turbulence caused by factors such as the 2008 financial crisis, the COVID-19 pandemic, and ongoing trade wars among global steel producers. These forces exposed the vulnerability of traditional steel manufacturing centers in Europe, including the Czech Republic, to international competition and structural shifts in global trade.

One of the most pertinent global challenges is the issue of overcapacity, primarily originating from Asia. In particular, China now produces more steel than the rest of the world combined, supplying more than 50% of global production. State-subsidized steel from China, combined with protectionist measures employed by countries like the United States, has fundamentally altered the dynamics of global steel trade. The overproduction of steel has saturated markets, created extreme price volatility, and forced many European steel producers to operate on increasingly narrow profit margins. For Czech producers, who rely heavily on exports to key European Union markets, these developments have undermined their ability to remain competitive, especially in sectors characterized by price-sensitive demand.

In parallel, structural weaknesses within European steel markets, such as declining demand in traditional sectors like automotive and construction, present further complications. With vehicle manufacturing accounting for approximately 30% of Czech steel output, a slowdown in the automotive sector has an outsized impact on steel manufacturers. Construction, requiring long lead times and extensive capital investment, has also experienced contraction in some markets, further straining steel producers' revenue streams.

Environmental factors have added yet another layer of complexity, particularly with the advent of the European Green Deal and the pressing need to reduce emissions. Carbon-heavy industries, such as steelmaking, are under unprecedented pressure to transition toward greener technologies to meet strict decarbonization targets. As of 2023, the steel industry accounts for 7% of global greenhouse gas emissions, a figure that highlights the significant environmental footprint of traditional steel production processes. Transitioning to greener technologies such as hydrogen-based direct reduction or electric arc furnaces presents an opportunity to align with future regulatory frameworks but demands large-scale financial investment, technical orchestration, and state support, which remain challenging for Czech producers to access at scale.

Beyond environmental regulations, rising costs in essential inputs - such as energy, raw materials, and labor - are eroding the profitability of Czech steel production. Electricity prices in the European Union are among the highest globally, driven by the adoption of ambitious decarbonization plans and a reliance on imported energy resources. Steelmaking's inherently energy-intensive nature places Czech producers at a competitive disadvantage compared to lower-cost regions such as Asia and the United States, where energy resources are often more affordable and less regulated.

This study contributes to the existing literature and policy discourse in several important ways. First, it provides a comprehensive empirical analysis of the Czech steel industry's performance from 2008 to 2023, utilizing official statistical data to document quantitative trends in production, employment, financial stability, and competitiveness that have not been systematically analyzed in recent academic literature. Second, the research adopts a holistic approach to identifying and

analyzing systemic risks, examining how global overproduction, regulatory compliance costs, energy price volatility, and workforce challenges interact to create cumulative pressures on industry sustainability. Third, the study offers evidence-based strategic recommendations that balance technological modernization requirements with policy frameworks needed to align the sector with EU decarbonization goals while maintaining economic viability. Finally, this analysis contributes to broader discussions on industrial transformation in Central and Eastern Europe, providing insights applicable to other traditional heavy industries navigating the transition toward sustainable production while preserving their strategic economic importance.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature on the Czech steel industry, covering material properties, Industry 4.0 integration, environmental sustainability, and global trade dynamics. Section 3 outlines the methodology employed, including data sources and analytical approaches. Section 4 presents key empirical findings on production trends, workforce dynamics, financial performance, and operational efficiency. Section 5 examines the primary challenges and risks facing the industry, while Section 6 provides strategic recommendations for modernization and sustainability. Section 7 discusses the critical role of policy and collaboration in supporting industry transformation. Finally, Section 8 concludes with implications for the future outlook of the Czech steel sector.

2. Literature Review

The Czech steel industry has undergone significant transformations over the years, shaped by various factors including technological advancements, economic policies, and market dynamics. This literature review synthesizes key findings from relevant studies that highlight the characteristics, challenges, and future directions of the Czech steel sector.

One of the foundational aspects of the Czech steel industry is its material properties and reliability. Research by Kala *et al*., [1] emphasizes the importance of statistical analysis in understanding the material and geometrical characteristics of structural steels produced by dominant Czech manufacturers. Their findings on yield strength, tensile strength, and ductility have provided essential data for reliability studies, particularly using the Monte Carlo method, which has gained traction due to advancements in computational capabilities. Further, Kala [2] work on fuzzy probabilistic analysis illustrates the necessity of maintaining consistent quality across metallurgical production in the EU, showcasing the statistical characteristics of yield stress and tensile strength of Czech steel. This focus on material properties is critical as it directly influences the structural integrity and safety of steel products used in construction and manufacturing.

The integration of Industry 4.0 technologies presents both opportunities and challenges for the Czech steel industry. Research indicates that many small and medium-sized enterprises (SMEs) in the Czech Republic are exploring the adoption of these technologies to enhance efficiency and competitiveness [3]. However, the readiness of these enterprises to implement such innovations varies significantly, with a considerable percentage acknowledging the importance of Industry 4.0 for their future [4]. This disparity in readiness highlights the need for targeted strategies to improve human capital and technological adoption within the sector [5]. Moreover, the correlation between digital transformation and productivity gains in the steel industry is becoming increasingly evident, as firms that align with Industry 4.0 principles tend to perform better in international markets [6].

Environmental sustainability is another pressing issue facing the Czech steel industry. The industry's response to carbon neutrality goals is critical, especially in light of the economic challenges posed by the COVID-19 pandemic [7]. The transition towards greener production methods is not only a regulatory requirement but also a market demand, as consumers and stakeholders increasingly

prioritize sustainability [8]. Research has shown that the Czech steel sector must adapt its production structures to align with global sustainability trends, which may involve significant investments in new technologies and processes [9]. Recent research by Macek and Vitásek [10] on ESG risk analysis and preparedness of companies in the Czech Republic highlights the growing importance of environmental, social, and governance factors in corporate risk management, providing valuable insights into how Czech industrial companies, including those in the steel sector, are adapting to sustainability requirements and managing ESG-related risks in their operations.

Furthermore, the competitive landscape of the Czech steel industry is influenced by its integration into global production networks. The ability of Czech firms to compete on an international scale is often contingent upon their participation in these networks, which can enhance access to resources, markets, and technological advancements [11]. The interplay between local capabilities and global market demands necessitates a strategic approach to foreign direct investment and collaboration with international partners [12].

Decarbonization is a pressing concern for the steel industry, which is responsible for approximately 27% of global carbon dioxide emissions from manufacturing [13]. The transition towards low-carbon technologies is essential for reducing the industry's carbon footprint. Frey *et al.,* [14] discuss initiatives like Carbon2Chem, which aim to exploit synergies between the steel and chemical industries to utilize steel mill off-gases as raw materials, thereby minimizing emissions while enhancing value chains. Furthermore, Yang [15] research highlights the role of big data in monitoring carbon emissions, suggesting that improved data accuracy can facilitate more effective emission reduction strategies.

Modernization of the steel industry is closely linked to the adoption of Industry 4.0 technologies, which encompass automation, data exchange, and advanced manufacturing techniques. Gajdzik and Wolniak [5] provide a thorough review of the transition from Steelworks 3.0 to Steelworks 4.0, emphasizing the need for digitalization and the implementation of smart technologies to enhance operational efficiency [16]. The integration of intelligent manufacturing technologies, as discussed by Zhou *et al.*, [17] is crucial for boosting productivity and flexibility in steel production processes. Moreover, the literature indicates that energy efficiency improvements are a significant focus area, with studies showing that investments in new technologies can lead to substantial reductions in energy intensity [18, 16].

Global trade dynamics also play a vital role in shaping the steel industry. The competitive landscape is influenced by the interconnectedness of national and international markets, where countries like China dominate production, accounting for over half of global steel output [19]. The restructuring of the steel industry in response to environmental regulations and market demands necessitates a reevaluation of production structures and trade relationships [20]. Conejo *et al.,* [21] highlights the environmental challenges faced by the steel industry's value chain, underscoring the need for sustainable practices that align with global trade requirements. Additionally, the identification of energy efficiency trends in the context of Industry 4.0, as explored by Wolniak *et al.*, [22] suggests that modernization efforts can enhance competitiveness in global markets.

Product innovation plays a vital role in the steel industry's response to the European Green Deal. Axelson *et al.,* [23] discuss how business model innovation (BMI) is integral to emission reduction strategies, emphasizing that both incremental and radical innovations are necessary for the industry's transition to sustainability. The authors suggest that firms must engage in innovative practices to improve their sustainability performance, which can lead to enhanced competitiveness. Furthermore, Suer *et al.,* [24] emphasizes the importance of life cycle assessments (LCA) in evaluating the environmental impacts of different steel production methods, advocating for the adoption of

breakthrough technologies to achieve environmentally friendly production. This focus on innovation addresses environmental concerns and positions companies to meet changing market demands.

Competitiveness in the global steel market is increasingly linked to sustainability practices. Watari [25] indicates that the feasibility of meeting global steel demand within carbon budgets poses significant challenges, necessitating strategic investments in decarbonized production processes. The author argues that industries must adapt to these challenges by enhancing the value of their products through innovative approaches, such as selling materials as services rather than commodities. This shift can improve market positioning and align with the sustainability goals outlined in the European Green Deal.

Moreover, the literature highlights the importance of collaboration and knowledge sharing among stakeholders in the steel industry to foster innovation and improve energy efficiency. The work of Tian *et al.,* [26] suggests that the integration of carbon capture and storage technologies can significantly contribute to decarbonization efforts, thereby enhancing the industry's overall sustainability. Collaborative initiatives that promote research and development in low-carbon technologies are essential for the steel sector to remain competitive in a global market increasingly focused on sustainability.

3. Methodology

This study combines a range of quantitative and qualitative methods to analyze the challenges and opportunities for the Czech steel industry from 2008 to 2023. The primary goal is to examine the key external and internal factors affecting the sector's competitiveness, sustainability, and compliance with evolving environmental regulations, while also identifying actionable solutions for its modernization and long-term survival.

The data for this study was sourced from several reliable institutions, including the Czech Statistical Office (ČSÚ) for macroeconomic and industry-specific indicators, such as production volumes, exports, employment trends, and financial performance. Additional insights were derived from reports by the Ministry of Industry and Trade of the Czech Republic, which included industrial strategies and environmental compliance frameworks. At the international level, data from organizations like the World Steel Association, OECD, and European Commission informed the comparative analysis, particularly in terms of global production trends, trade policies, and decarbonization measures. Corporate reports from leading Czech steel producers, such as Třinecké železárny and Liberty Ostrava, provided a deeper understanding of operational efficiency and technological adoption in the sector. Academic studies and independent industry analyses further enriched the contextual understanding of challenges related to globalization, emissions compliance, and innovation.

The analysis integrates statistical methods to evaluate industry trends, focusing on financial indicators like revenue, liabilities, and profitability over the study period. Comparisons with regional and global competitors highlight the Czech steel industry's relative position in terms of productivity, cost structures, and regulatory impacts. To evaluate environmental challenges, the study assesses the implications of the European Green Deal and explores the costs and opportunities of implementing decarbonization technologies, such as electric arc furnaces and hydrogen-based production systems.

Scenario modeling was employed to project future developments under varying conditions, examining how different policy measures, global market shifts, and energy price fluctuations could affect the industry's resilience. While the analysis provides valuable insights, certain limitations exist, including reliance on secondary data and inherent uncertainties around future technological

advancements. Nonetheless, the methodology ensures a comprehensive exploration of the steel industry's current state and potential pathways to sustainability.

4. Key Data and Insights on the Czech Steel Industry

This section presents a series of key data points and analyses to provide a detailed understanding of the challenges faced by the Czech steel industry. Each subsection introduces important trends described through graphs, accompanied by in-depth explanations. These visuals place the Czech steel industry in context, comparing its performance with competitors and examining the implications of global and domestic pressures.

4.1 Production and Revenue Trends - Structural Volatility

The performance of the Czech steel industry has undergone significant fluctuations over the 2008–2022 period, reflecting its sensitivity to global economic disruptions and structural challenges. Figure 1 shows the development of revenues in the steel sector, which peaked in 2008 at over 550 billion CZK before falling sharply during the global financial crisis to 385 billion CZK in 2009. This decline was driven by reduced industrial demand, particularly in construction and automotive sectors. After this drop, revenues gradually recovered, stabilizing from 2010 to 2019, though pre-crisis levels were not fully regained due to increased competition, stagnating investments, and growing price pressures.

The COVID-19 pandemic in 2020 created another sharp decline as demand weakened while supply chains were heavily disrupted. However, by 2021 and 2022, revenues rebounded significantly, reaching a historic high of over 826 billion CZK in 2022. This sharp recovery reflects rising raw material prices, inflation, and renewed demand in key export markets, rather than systematic structural improvements.

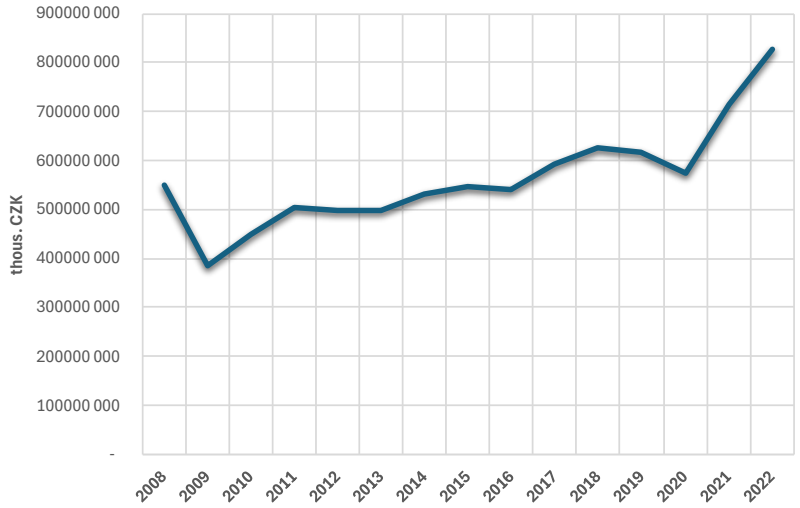

Fig. 1. Revenues in the Czech Steel Industry (2008-2022). Source: The Czech Statistical Office, Ministry of Industry and Trade of the Czech Republic, own processing, 2024

Figure 2 shows the steel sector's share of total manufacturing revenues over time. In 2008, steel accounted for 15.44% of manufacturing revenues. This share dropped to 12.80% in 2009 due to the financial crisis and remained around 12–13% over the following decade. By 2022, this share climbed back to 13.97%, showing recovery but underscoring the industry's diminishing role in the broader manufacturing landscape.

These trends highlight the Czech steel industry's vulnerability to external shocks and its reliance on short-term external factors like market price rises, rather than long-term competitiveness improvements. To ensure sustainable growth, the sector must address structural challenges, modernize production facilities, and invest in innovation.

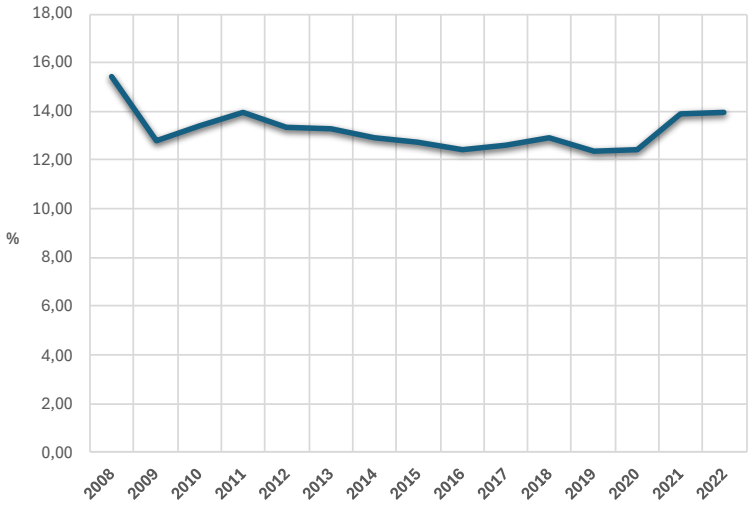

Fig. 2. Share of Steel Sector Revenues in Total Manufacturing Revenues (2008-2022). Source: The Czech Statistical Office, Ministry of Industry and Trade of the Czech Republic, own processing, 2024

4.2 Workforce and Wage Trends

The human capital of the steel industry plays a crucial role in maintaining its efficiency and competitiveness. However, data from the Czech steel industry reveals a steady decline in the average number of employees over the period from 2008 to 2022, accompanied by a consistent increase in average wages. These trends reflect structural adjustments in the sector as well as broader labor market dynamics.

Figure 3 outlines changes in the average number of employees in the steel industry, which fell from approximately 205,000 in 2008 to around 189,000 in 2022. This reduction reflects efforts to streamline operations and adopt more automated processes, driven by increasing competition and cost pressures. While automation has improved productivity, it has also contributed to job losses, particularly in routine and non-specialized roles. The intensity of these declines is most evident during major economic downturns, such as the 2008–2009 global financial crisis and the COVID-19 pandemic in 2020, when firms sought to cut costs in response to falling demand.

In contrast, Figure 4 shows a rise in the average wage per employee, which increased from 21,713 CZK per month in 2008 to over 39,000 CZK in 2022. This growth is driven partly by inflationary trends and partly by the increasing demand for highly skilled employees capable of managing advanced production processes. Additionally, the declining pool of skilled labor, exacerbated by reduced enrollments in technical education programs, has put upward pressure on wages to attract and retain talent.

These contrasting trends highlight two challenges for the Czech steel industry. First, while workforce reductions have addressed cost efficiency, they have created a growing skills gap as roles become more specialized. Second, the increasing labor costs underscore the need for investment in training and education programs to ensure the steel industry can meet future technological and production needs. Strengthening partnerships between industry, government, and educational

institutions is essential to building a sustainable and skilled workforce for the sector's long-term viability.

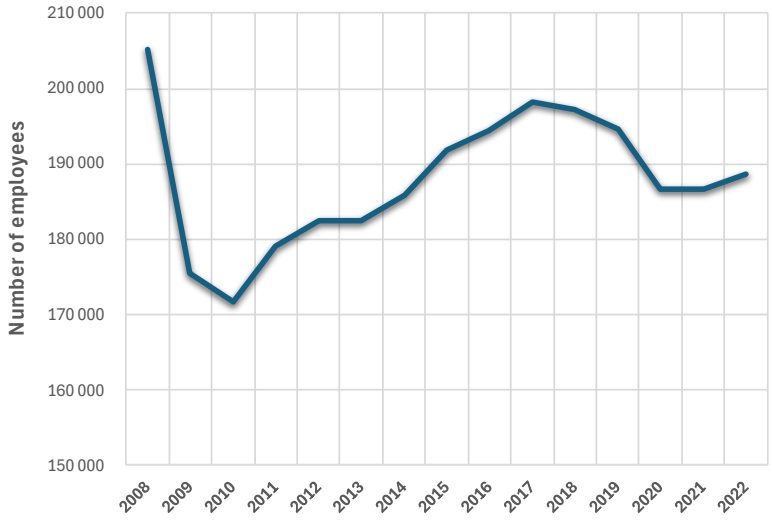

Fig. 3. Average Number of Employees in the Czech Steel Industry (2008-2022). Source: The Czech Statistical Office, Ministry of Industry and Trade of the Czech Republic, own processing, 2024

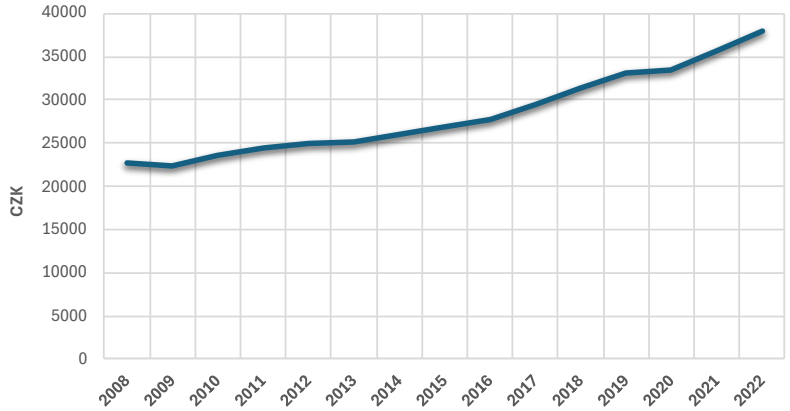

Fig. 4. Average Monthly Wage in the Czech Steel Industry (2008-2022). Source: The Czech Statistical Office, Ministry of Industry and Trade of the Czech Republic, own processing, 2024

4.3 Capital Structure and Financial Stability

The capital structure of the Czech steel industry provides important insights into its financial health and capacity to navigate economic challenges. Data on total assets, liabilities, and equity from 2008 to 2022 illustrate the industry's ability to adapt to crises while highlighting areas in need of improvement to maintain long-term stability.

Figure 5 shows the development of total assets of the Czech steel industry, which amounted to approximately 419 billion CZK in 2008. During the global financial crisis in 2009, total assets declined to 388 billion CZK as companies faced reduced demand and limited investment flows. The recovery that followed was gradual, with assets growing steadily after 2015, reaching 628 billion CZK in 2022. This growth reflects industry-wide investment in modernization, including new machinery and

production facilities. However, the growth has not been uniform, as market volatility and resource constraints have periodically slowed investment activity.

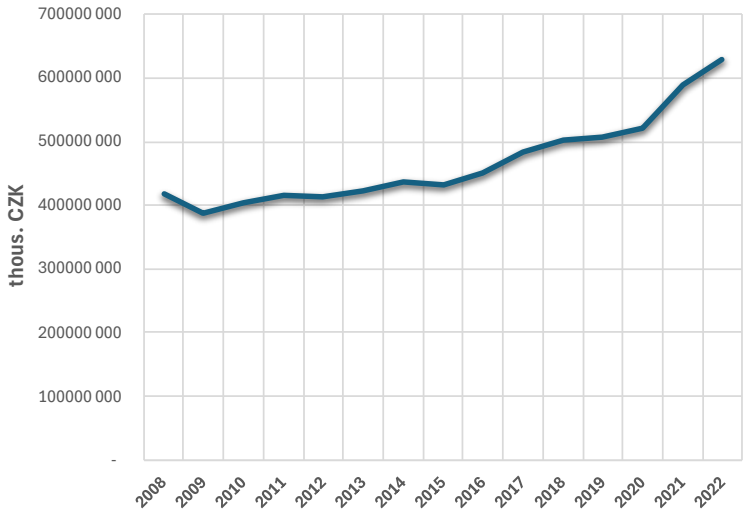

Fig. 5. Total Assets in the Czech Steel Industry (2008-2022). Source: The Czech Statistical Office, Ministry of Industry and Trade of the Czech Republic, own processing, 2024

Figure 6 illustrates the development of total liabilities in the Czech steel industry from 2008 to 2022. Liabilities grew from 190.5 billion CZK in 2008 to 287.5 billion CZK in 2022, highlighting the increasing reliance on external financing to sustain operations and invest in equipment and modernization. This trend demonstrates how companies turned to borrowed capital, particularly during periods of financial hardship, as seen during the global economic crisis in 2009 and the COVID-19 pandemic in 2020. These financing practices allowed firms to navigate short-term challenges but simultaneously increased their exposure to debt repayments and interest expenses, potentially complicating future investment strategies. While higher liabilities reflect ongoing financial activity, they also signal growing vulnerability, particularly under tightening credit conditions or shifting global market dynamics.

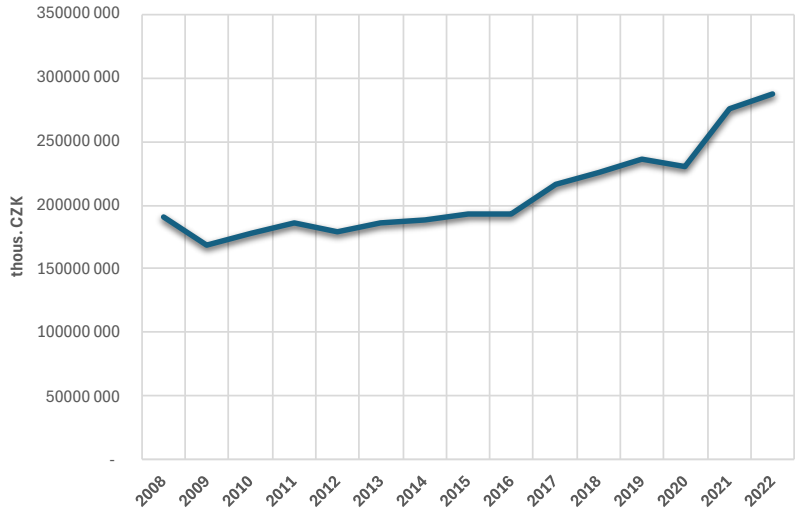

Fig. 6. Total Liabilities in the Czech Steel Industry (2008-2022). Source: The Czech Statistical Office, Ministry of Industry and Trade of the Czech Republic, own processing, 2024

Figure 7 focuses on total equity, which rose from 216 billion CZK in 2008 to 329 billion CZK in 2022. The steady growth in equity indicates the industry's ability to retain earnings and reinvest in productive assets, even in the face of economic uncertainties. Equity increases during this period were supported by efforts to rebuild after the significant shocks caused by the 2008 financial crisis and the pandemic, reflecting the resilience of steel producers in maintaining profitability over the long term. However, the slower growth in equity as compared to liabilities highlights ongoing challenges in maintaining a balanced financial structure. While the industry has made strides in strengthening its financial base, the reliance on external financing outpaces proportional equity growth, potentially straining companies' financial flexibility and limiting their capacity to absorb additional costs, such as decarbonization and environmental compliance investments.

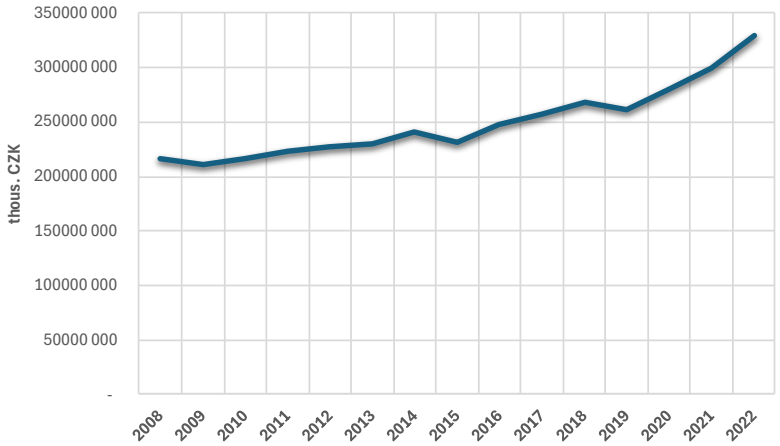

Fig. 7. Total Equity in the Czech Steel Industry (2008-2022). Source: The Czech Statistical Office, Ministry of Industry and Trade of the Czech Republic, own processing, 2024

Together, the trends in liabilities and equity underline the Czech steel sector's efforts to stay financially sustainable while handling mounting pressures from economic disruptions and market shifts. However, the heavier reliance on liabilities also points to the need for enhanced financial strategies, such as improving capital efficiency, diversifying funding sources, and securing public or private support for major investment projects. Long-term fiscal sustainability will likely depend on balancing liability growth with proportional equity increases while reducing exposure to high interest payments.

4.4 Profitability and Operating Efficiency

The profitability and operating performance of the Czech steel industry over the period 2008–2022 reflect its resilience to economic disruptions and its ability to adapt to market conditions. The evolution of Earnings Before Interest and Taxes (EBIT) offers key insights into the sector's financial health and efficiency amidst fluctuating external pressures.

Figure 8 displays yearly EBIT data for industry. In 2008, EBIT stood at 39.7 billion CZK, demonstrating strong performance before the onset of the global financial crisis. The crisis had a dramatic impact, with EBIT plummeting to just 11.8 billion CZK in 2009 as demand contracted across key sectors and revenue streams diminished. Recovery was slow but steady throughout the subsequent decade, with the sector benefitting from gradual improvements in export demand, particularly within the European Union. By 2015, EBIT recovered to 43.6 billion CZK, underscoring the sector's adaptability.

Fig. 8. EBIT in the Czech Steel Industry (2008-2022). Source: The Czech Statistical Office, Ministry of Industry and Trade of the Czech Republic, own processing, 2024

However, the COVID-19 pandemic presented new challenges, causing EBIT to decline significantly in 2020 to 39.4 billion CZK. This dip reflected the challenges of weakened demand, supply chain disruptions, and the high fixed costs of steel production. Despite these obstacles, the industry demonstrated flexibility, achieving a strong rebound by 2021 with EBIT increasing to 62.9 billion CZK, driven by recovering international demand and rising steel prices.

While the recovery in profitability is commendable, underlying concerns remain. Rising energy costs, stricter environmental regulations, and increased competition from low-cost global producers threaten sustained profit levels. The data highlights the need for a proactive focus on operating efficiency, cost optimization, and transitioning to higher-value steel products to sustain profitability under evolving market dynamics.

Investing in modernization, energy efficiency, and innovation will be vital to ensuring long-term operational efficiency and protecting profitability. Furthermore, the sector must align its strategies with EU decarbonization policies to remain competitive in an increasingly environmentally conscious market.

5. Challenges and Risks for the Czech Steel Industry

The Czech steel industry, like its European counterparts, faces a range of structural and emerging challenges that threaten its sustainability and competitiveness. These challenges stem from both internal factors, such as rising production costs, and external pressures, including globalization, regulatory demands, and fluctuating market dynamics. Understanding these challenges is essential for formulating strategies to safeguard the long-term prosperity of this strategic sector.

One of the most significant risks confronting the Czech steel industry is the persistence of global overproduction. According to recent data, the global steel market has been characterized by chronic overcapacity, with countries like China producing more than half of the world's total steel output. This surplus exerts downward pressure on global prices and makes it increasingly difficult for Czech producers to compete. Low-cost producers in Asia, backed by state subsidies and less stringent environmental regulations, flood international markets, undermining the market share of EU and Czech producers. The Czech steel industry, which relies heavily on exports, particularly to Germany and other EU economies, is particularly vulnerable to this form of market distortion.

Rising production costs represents another critical challenge. Steelmaking is an energy-intensive process, and the industry has been disproportionately affected by volatile energy prices in recent years. The Czech Republic has some of the highest electricity costs in Europe, driven by the transition

to renewable energy and the associated infrastructure investments. These costs have only been exacerbated by the EU's emissions trading system (ETS), which imposes significant financial obligations on carbon-intensive industries. Czech steel producers, many of whom still rely on traditional blast furnace technologies, are heavily burdened by these expenses. Unlike competitors in China or India, which benefit from state-subsidized energy prices, Czech companies face rising operational costs that erode their margins and reduce their capacity to invest in modernization.

Environmental compliance adds another layer of risk. While the ambition of the European Green Deal - making the EU's economy carbon-neutral by 2050 - is clear, it places significant pressure on industries like steel, which are responsible for high greenhouse gas emissions. Steel production accounts for 7% of global CO2 emissions, and Czech producers, operating primarily through carbon-intensive methods, struggle to meet the EU's stringent decarbonization targets. Technologies such as electric arc furnaces and hydrogen-based direct reduction offer pathways to lower emissions but require substantial capital investments. Many Czech producers lack the financial resources to implement such changes without substantial government support or access to EU funding mechanisms like the Innovation Fund or the Modernization Fund.

Declining demand in traditional steel-consuming sectors further compounds these risks. The automotive industry, one of the Czech steel industry's largest consumers, has faced disruption in recent years, first from the COVID-19 pandemic and later from the semiconductor shortage and economic slowdowns in key markets. Similarly, stagnation in the construction sector, another critical steel-consuming industry, has weakened demand for basic steel products. These shifts create additional uncertainties for Czech producers, who must balance immediate revenue pressures with the need for long-term investments in modernization and product diversification.

International competition continues to pose a formidable challenge. Not only do Czech producers face competition from global low-cost exporters, but they are also increasingly challenged by intra-European rivals. Countries such as Germany and Sweden operate with more advanced production facilities and financial resources, allowing them to adopt cleaner and more efficient technologies. Without comparable modernization, Czech steel producers risk losing their competitive edge, even within the EU market.

Policy uncertainty is another risk factor. While the EU has implemented trade defense measures, such as import tariffs and anti-dumping duties, enforcement and efficacy remain inconsistent. Czech producers continue to feel the impact of cheap imports, particularly from non-EU countries. Furthermore, the absence of a clear, long-term national strategy for the steel industry complicates efforts to align industrial objectives with broader EU goals. Producers face difficulties planning in this uncertain regulatory and policy environment.

Labor market dynamics add yet another dimension to the industry's challenges. The average number of employees in the Czech steel sector has steadily declined over the last decade as firms have pursued automation to enhance efficiency. However, this pursuit has created a growing skills gap. A shrinking workforce and a lack of new entrants into the industry, especially from technical and vocational schools, threaten the sector's ability to maintain specialized operations. Rising wage costs, necessitated by labor shortages and inflation, creates further pressure on producers' finances.

Collectively, these challenges place the Czech steel industry at a crossroads. Its ability to remain viable in a fiercely competitive and environmentally conscious global market depends on how well it can address these vulnerabilities. Structural issues like high energy costs and reliance on outdated technologies must be tackled through effective modernization and greater policy support. At the same time, Czech producers will need to respond to market requirements by developing higher-value steel products, exploring new markets, and aligning with global trends in green production. Without

decisive action, the industry risks losing its strategic importance both domestically and internationally.

6. Strategic Recommendations for the Czech Steel Industry

To address the challenges outlined in the previous chapter and secure the long-term sustainability of the Czech steel industry, decisive action is required. A combination of modernization initiatives, investment in green technologies, and policy support is essential for enhancing competitiveness and aligning the sector with global industrial and environmental trends. The following recommendations highlight key areas where both the industry and policymakers can drive transformation.

Modernization of production processes remains critical for the Czech steel industry's survival in a competitive global market. Adopting advanced production technologies, such as electric arc furnaces (EAF), can significantly reduce emissions, energy consumption, and operating costs compared to traditional blast furnaces. Transitioning to EAF-based production will not only improve environmental compliance with EU decarbonization targets but also enhance operational flexibility by enabling the use of recycled steel, an increasingly valuable resource within the circular economy. Additionally, Czech producers must explore emerging technologies, such as hydrogen-based steel production, which has the potential to achieve near-zero emissions. While hydrogen adoption is costly and infrastructure-dependent, securing government grants and EU funding will be pivotal in building the necessary foundation for its implementation.

Energy efficiency and cost optimization should be at the forefront of industry priorities. Rising electricity prices in the Czech Republic have amplified production costs, leaving companies at a disadvantage compared to competitors in regions with state-regulated or subsidized energy. Investing in energy-efficient technologies, such as heat recovery systems, and diversifying energy sources by incorporating renewable energy partnerships can help mitigate these challenges. Policymakers can support this transition by introducing energy price stabilization policies and providing financial incentives for implementing energy-saving technologies. Innovative solutions, such as small modular nuclear reactors, could be explored as longer-term strategies for stabilizing energy supply while reducing carbon footprints.

Product innovation must play a central role in ensuring the future competitiveness of the Czech steel industry. Higher-value specialized steel products, such as lightweight alloys and high-strength materials for green energy infrastructure, advanced transportation systems, and construction, represent key growth opportunities. Diversifying product portfolios will allow Czech producers to secure niche markets, reducing dependence on highly commoditized and price-sensitive products. Collaborations with research institutions and universities should be strengthened to accelerate innovation and provide pathways toward producing the next generation of steel products tailored to evolving industrial needs.

For enterprises to succeed, policy-level assistance is indispensable. Government-backed grants, tax incentives, and accessible loans should be deployed to alleviate the financial burden of decarbonization and modernization efforts. Policymakers should also act as mediators to enhance access to EU funds, such as the Innovation Fund and Modernization Fund, which can finance the large-scale infrastructure needed for low-imission steel production technologies. Furthermore, enforcing fair trade policies within the European Union to counteract the impact of low-cost steel imports will be critical in protecting domestic producers. This can be complemented by pushing for stricter anti-dumping measures and expanding tariffs on steel from non-EU markets that do not meet strict environmental regulations.

Strategic partnerships, both domestic and international, hold immense potential to expand the industry's capabilities. On the domestic front, fostering closer collaboration between the steel sector, government bodies, and regional stakeholders will align strategic objectives and enable a coordinated approach. Internationally, participation in European industrial alliances focused on decarbonization can provide expertise, shared infrastructure, and economies of scale for adopting clean technologies. This ensures Czech steel producers remain part of the broader European steel transition, leveraging collective resources to meet common goals.

Finally, workforce development and talent retention must not be overlooked. The shortage of skilled labor in the steel sector poses significant long-term risks. Reforming technical education systems to attract young talent into the industry is vital. State-sponsored retraining and upskilling programs for existing workers can ensure they are equipped to navigate the advanced technological demands of a modernized steel production ecosystem. By fostering strong industry-academia partnerships, these initiatives can develop a sustainable pipeline of expertise critical for the future.

In summary, the Czech steel industry stands at a critical juncture. Enhancing competitiveness and sustainability requires simultaneous efforts across multiple fronts, including modernization, product innovation, cost optimization, policy support, and workforce development. A strategic, collaborative approach that aligns the interests of producers, policymakers, and other stakeholders will be pivotal in securing the future of this vital sector. Failure to act decisively risks not only the decline of the Czech steel industry but also the erosion of its strategic economic importance within Europe and beyond.

7. Role of Policy and Collaboration

The future of the Czech steel industry depends not only on the efforts of individual companies but also on effective collaboration between government institutions, policymakers, and other stakeholders. The challenges inherent to the sector - ranging from high production costs to compliance with EU decarbonization targets - necessitate coordinated policy intervention and public-private partnerships. This chapter examines the critical role that policy and collaboration must play in supporting the industry's transition toward sustainability and competitiveness.

Effective trade policies are essential to maintaining the competitiveness of Czech steel producers in a global market increasingly dominated by low-cost exporters, such as China and India. While the European Union has implemented protective measures, including anti-dumping tariffs and import quotas, these policies require stricter enforcement to ensure their effectiveness. Expanding these measures to cover emerging challenges, such as non-EU producers bypassing existing trade rules, is vital. Additionally, more robust implementation of mechanisms like the Carbon Border Adjustment Mechanism (CBAM) can level the playing field by penalizing imports from countries with lax environmental regulations. These measures would reduce the competitive disadvantage Czech producers face and incentivize a broader global shift toward greener practices.

Government support is fundamental for enabling the Czech steel industry to meet the ambitious decarbonization goals set by the European Green Deal. Electrifying steel production, transitioning to hydrogen-based processes, and implementing carbon capture and storage technologies require substantial financial investments, often beyond the capacity of private enterprises. Policymakers should prioritize facilitating access to EU funds, such as the Innovation Fund and Modernization Fund, which are explicitly designed to support industries in implementing decarbonization projects. In addition to EU-level funding, national subsidy programs should be expanded to cover upgrades to cleaner production technologies and innovations that lower operational emissions.

As energy costs continue to rise, energy policy will play a critical role in stabilizing the operational environment for Czech steel producers. Specifically, long-term agreements between the government and energy suppliers can ease cost pressures by ensuring predictable energy pricing for energy-intensive industries like steel production. Investments in energy diversification—such as renewable energy partnerships or the exploration of small modular nuclear reactors—can provide cost-effective alternatives for steelmakers while aligning with long-term sustainability goals.

Collaborative initiatives between policymakers, industry leaders, and regional stakeholders can unlock further potential for the Czech steel industry. Local governments, in coordination with national institutions, should create region-specific strategies that leverage the steel sector's unique role in economic development, particularly in regions like Moravia and Silesia, where steel production remains a central driver of employment and industrial activity. Public-private partnerships can reduce financial risks for producers while promoting effective resource allocation in workforce development, energy resilience, and innovation.

Education policy and workforce collaboration are key to addressing the talent gap in the Czech steel industry. Policymakers should work with industry stakeholders to reform technical education programs, ensuring they align with the skills required for modernized, tech-driven steel production processes. By supporting the development of vocational and higher education programs focused on metalworking, engineering, and automation, the government can foster a steady pipeline of skilled workers. Apprenticeships, internships, and public-private co-investment in workforce training initiatives can prepare the next generation of workers while reducing labor shortages.

Finally, fostering international collaboration between Czech steel producers and their EU counterparts is crucial for long-term sustainability. Participation in European industrial alliances dedicated to decarbonization, research, and innovation can provide Czech producers access to shared expertise, joint infrastructure, and cooperative financing opportunities. Aligning with broader European efforts not only strengthens the industry’s position within the EU steel market but also ensures compliance with evolving EU policies while maintaining competitiveness in the global market.

In conclusion, policy and collaboration form the foundation upon which the Czech steel industry can navigate its challenges and secure its future. Striking a balance between protective measures, financial support, and long-term investments in energy, technology, and talent will require a coordinated effort between multiple stakeholders. Policymakers, as facilitators, must work hand-in-hand with industry leaders to foster resilience, innovation, and sustainability, ensuring the steel sector remains a strategic pillar of the Czech economy. Without such a framework, the industry's ability to compete and adapt to a rapidly transforming industrial environment may be compromised.

8. Conclusion and Future Outlook

The Czech steel industry stands at a critical crossroads, facing significant challenges while also possessing vast opportunities for sustainable development. Its historical importance to the national economy, combined with its role as a key supplier to strategic industries such as automotive, construction, and energy, underscores the necessity of preserving and transforming this vital sector. However, the industry's ability to remain competitive and relevant in the global market depends on its capacity to address rising production costs, regulatory pressures, and international overcapacity.

The analysis throughout this study highlights several critical vulnerabilities. Global overproduction, particularly from low-cost producers such as China and India, continues to erode the competitiveness of Czech steelmakers by creating downward price pressures. At the same time, rising energy costs and the financial strain of complying with EU decarbonization initiatives place domestic

producers at a financial disadvantage relative to their international counterparts. Demand fluctuations in traditional markets, coupled with stagnant investments in modernization, further exacerbate the industry's structural issues.

Yet, the Czech steel industry has demonstrated remarkable resilience in recovering from successive economic shocks, including the 2008 financial crisis and the COVID-19 pandemic. Its ability to rebound, as evidenced by trends in revenue, employment, and financial stability, indicates an inherent capacity for adaptation and growth. To capitalize on this potential, the industry must embrace a forward-looking strategy centered on innovation, sustainability, and collaboration.

A strategic roadmap for the future of Czech steel involves coordinated efforts across multiple dimensions. First, the sector must prioritize modernization through investment in clean technologies, such as electric arc furnaces and hydrogen-based steel production, to achieve both operational efficiency and compliance with EU emissions targets. Second, diversification into high-value steel products can help reduce reliance on price-sensitive commodity markets and open new opportunities in technologically advanced and green sectors. Third, collaboration with policymakers at both national and EU levels will be crucial to securing financing for large-scale infrastructure projects and ensuring fair trade practices that protect domestic producers from unfair competition.

Moreover, addressing the industry's workforce challenges will require targeted educational reform and training programs to attract and retain skilled talents capable of navigating the demands of advanced steel production technologies. Initiatives aimed at fostering closer cooperation between companies, universities, and technical schools will be key to bridging the skills gap in the sector.

Looking to the future, sustainability must remain at the core of the Czech steel industry’s aspirations. Aligning with the European Green Deal and global decarbonization trends not only fulfills critical environmental obligations but also presents an opportunity to reposition Czech steel as a leader in green manufacturing. Accessing EU funding mechanisms, forming international partnerships, and participating in regional cooperative efforts to develop environmentally friendly technologies will ensure that the sector remains relevant in a rapidly evolving marketplace.

In conclusion, while the Czech steel industry faces considerable obstacles, it also has the tools and opportunities to overcome them. By implementing a comprehensive strategy that balances innovation, sustainability, and policy support, the sector can secure its lasting role as a strategic pillar of the Czech economy. Failure to act decisively, however, risks the industry falling behind in an increasingly competitive and environmentally conscious global market. The choices made today will determine whether steel continues to shape the Czech Republic’s industrial identity well into the future.

Author Contributions

Conceptualization, B.K.; methodology, K.Č. and E.H.; formal analysis, E.H.; investigation, L.K.; resources, K.Č.; data curation, L.K.; writing—original draft preparation, B.K.; writing—review and editing, E.H. and M.K.; visualization, M.K.; supervision, B.K.; project administration, K.Č.; funding acquisition, K.Č. All authors have read and agreed to the published version of the manuscript.

Funding

This research was funded by GA AA, grant number GAAA/2024/5, name of the project: A multidisciplinary approach to housing investment.

Data Availability Statement

The data supporting the reported results were sourced from publicly available datasets from the Czech Statistical Office and the Ministry of Industry and Trade of the Czech Republic.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The funders had no role in the design of the study, in the collection, analyses and interpretation of data, in the writing of the manuscript and in the decision to publish the results.

Acknowledgement

This research was funded by GA AA, grant number GAAA/2024/5, name of the project: A multidisciplinary approach to housing investment.

References

[1] Kala, Z., Melcher, J., & Puklický, L. (2009). Material and geometrical characteristics of structural steels based on statistical analysis of metallurgical products. *Journal of Civil Engineering and Management, 15*(3), 299-307. https://doi.org/10.3846/1392-3730.2009.15.299-307

[2] Kala, Z. (2007). Fuzzy probabilistic analysis of steel structure focused on reliability design concept of Eurocodes. *Nonlinear Analysis Modelling and Control, 12*(3), 371-382. https://doi.org/10.15388/na.2007.12.3.14699

[3] Vrchota, J., Volek, T., & Novotná, M. (2019). Factors introducing industry 4.0 to SMES. *Social Sciences, 8*(5), 130. https://doi.org/10.3390/socsci8050130

[4] Vrchota, J., & Pech, M. (2019). Readiness of enterprises in Czech Republic to implement industry 4.0: Index of industry 4.0. *Applied Sciences, 9*(24), 5405. https://doi.org/10.3390/app9245405

[5] Vrchota, J., Maříková, M., Řehoř, P., Rolínek, L., & Toušek, R. (2020). Human resources readiness for industry 4.0. *Journal of Open Innovation: Technology, Market, and Complexity, 6*(1), 3. https://doi.org/10.3390/joitmc6010003

[6] Srivastava, M., & Tyll, L. (2020). The effect of industry-specific networking behaviour on the internationalization performance of Czech SMEs. *European Business Review, 33*(2), 361-382. https://doi.org/10.1108/ebr-10-2019-0244

[7] Hrubá, D., & Samolejová, A. (2020). The impact of carbon neutrality on human resources in the metallurgy industry. https://doi.org/10.37904/metal.2020.3640

[8] Markaki, M., Papadakis, S., & Putnová, A. (2021). A modern industrial policy for the Czech Republic: Optimizing the structure of production. *Mathematics, 9*(23), 3095. https://doi.org/10.3390/math9233095

[9] Xia, J., & Ahokainen, T. (2003). Homogenization of temperature field in a steelmaking ladle with gas injection. *Scandinavian Journal of Metallurgy, 32*(4), 211-217. https://doi.org/10.1034/j.1600-0692.2003.00642.x

[10] Macek, D., & Vitásek, S. (2024). ESG risk analysis and preparedness of companies in the Czech Republic. *International Journal of Economic Sciences, 13*(2), 38-54. https://doi.org/10.52950/ES.2024.13.2.003

[11] Pulec, J. (2016). Integration of the Czech brewing industry into global production networks. *Auc Geographica, 51*(1), 47-59. https://doi.org/10.14712/23361980.2016.5

[12] Soulsby, A. (2020). Foreign direct investment and the undertow of history: Nationhood and the influence of history on the Czech-German relationship. *Business History, 64*(4), 727-754. https://doi.org/10.1080/00076791.2020.1784878

[13] Jeong, S. (2015). System dynamics approach for the impacts of finex technology and carbon taxes on steel demand: Case study of the Posco. *International Journal of Precision Engineering and Manufacturing-Green Technology, 2*(1), 85-93. https://doi.org/10.1007/s40684-015-0011-1

[14] Frey, A., Goeke, V., & Voß, C. (2018). Steel gases as ancient and modern challenging resource; historical review, description of the present, and a daring vision. *Chemie Ingenieur Technik, 90*(10), 1384-1391. https://doi.org/10.1002/cite.201800046

[15] Yang, W. (2023). Correlation analysis and monitoring method of carbon emissions in the steel industry based on big data. *Strategic Planning for Energy and the Environment*. https://doi.org/10.13052/spee1048-5236.4312

[16] Gajdzik, B., & Wolniak, R. (2021). Transitioning of steel producers to the steelworks 4.0—literature review with case studies. *Energies, 14*(14), 4109. https://doi.org/10.3390/en14144109

[17] Zhou, D., Xu, K., Lv, Z., Yang, J., Li, M., He, F., & Xu, G. (2022). Intelligent manufacturing technology in the steel industry of China: A review. *Sensors, 22*(21), 8194. https://doi.org/10.3390/s22218194

[18] Gajdzik, B. (2020). Modelling the impact of investments on energy intensity in the polish steel industry as a step towards industry 4.0. https://doi.org/10.37904/metal.2020.3663
[19] Pian, F., Yao, X., & Shihua, P. (2021). Comparative study on industrial concentration degree of China, Japan, USA, Korea steel industry. *E3S Web of Conferences, 235*, 02002. https://doi.org/10.1051/e3sconf/202123502002
[20] He, K., Wang, L., & Li, X. (2020). Review of the energy consumption and production structure of China's steel industry: Current situation and future development. *Metals, 10*(3), 302. https://doi.org/10.3390/met10030302
[21] Conejo, A., Birat, J., & Dutta, A. (2020). A review of the current environmental challenges of the steel industry and its value chain. *Journal of Environmental Management, 259*, 109782. https://doi.org/10.1016/j.jenvman.2019.109782
[22] Wolniak, R., Saniuk, S., Grabowska, S., & Gajdzik, B. (2020). Identification of energy efficiency trends in the context of the development of industry 4.0 using the polish steel sector as an example. *Energies, 13*(11), 2867. https://doi.org/10.3390/en13112867
[23] Axelson, M., Oberthür, S., & Nilsson, L. (2021). Emission reduction strategies in the EU steel industry: Implications for business model innovation. *Journal of Industrial Ecology, 25*(2), 390-402. https://doi.org/10.1111/jiec.13124
[24] Suer, J., Traverso, M., & Jäger, N. (2022). Review of life cycle assessments for steel and environmental analysis of future steel production scenarios. *Sustainability, 14*(21), 14131. https://doi.org/10.3390/su142114131
[25] Watari, T. (2023). Feasible supply of steel and cement within a carbon budget is likely to fall short of expected global demand. *Nature Communications, 14*(1). https://doi.org/10.1038/s41467-023-43684-3
[26] Tian, S., Jiang, J., Zhang, Z., & Manović, V. (2018). Inherent potential of steelmaking to contribute to decarbonisation targets via industrial carbon capture and storage. *Nature Communications, 9*(1). https://doi.org/10.1038/s41467-018-06886-8