

Changes in the Steel Industry in Poland in the Period 1990 to 2020: Innovation and Digitisation on the Way to Steel Mills 4.0

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1. Introduction

In times of economic system transformation in Poland (such as in the 1990s), enterprises functioning across all branches of industry have transformed considerably. The transformations to market economy have a deep and radical character. The range of restructuring comprises all areas of the functioning of Polish enterprises. The restructuring changes are in technology, production, work, organisation and management. The changes were also present in the steel industry in Poland. The restructuring process in the steel industry consisted of the de-indebtedness of enterprises, reduction in employment, reduction in production volumes, withdrawal of old (uneconomic) technologies and enhancing productivity. Before the transformation of the economy in Poland (before 1989), there were no economic incentives for cost reduction, process optimisation, efficiency or profitability. Business objectives very often had political significance (Krajewski 2009). Production costs were high, too many workers were employed in steel mills, and the manufacturing technology was outdated and degraded the natural environment. Restructuring of the metallurgy industry in Poland started after 1990. Government programmes for the steel sector were implemented after that year. The time of restructuring of the steel industry in Poland included several distinct periods: In the first period, from 1992 to 1997, the Restructuring Programme for the Polish Steel Industry—developed in 1996 as part of the 1997 Industrial Policy—was implemented. In the second period, from 1998 to 2020, the “Restructuring Programme of the Iron and Steel Industry in Poland” was implemented. The document complied with European Union policy (this was during the period of Polish accession to the EU). The main objectives of the programme were the reduction in employment and the privatisation of steel mills. The next versions of the programme were presented under simplified titles: “Update 2001”, “Update 2002”, “Modification 2002”. In the third period, from 2003 to 2007, the last programme “Restructuring and development of the steel industry until 2006” was implemented (Gajdzik 2012). In 2007, the European Commission recognised the completion of the restructuring

process of Polish metallurgy (document: COMP/2006/SI2.435836). In the period 2007 to 2010, the EU continued to monitor the situation in the steel sector in Poland. The supervised restructuring of the steel industry in Poland was therefore finally completed in 2010 (Szulc 2014). The steel industry was adopted to situate itself in the European steel market (Gondys and Ślusarczyk 2010); In the next decade (2010 to 2020), Polish steel mills, already privatised and integrated into the structures of strong foreign capital groups in the global steel market (the largest steel producers in Poland belong to foreign owners: ArcelorMittal, CMC, Celsa) (Gajdzik and Sroka 2012), began their path to building competitiveness in the steel market. Building competitiveness, steel mills have implemented new technological investments (BAT) according to the principles of sustainability (Gajdzik and Burchart-Korol 2011; Kłosok-Bazan et al. 2015). The quality of steel products and innovative products play a special role in conducting business. Steel mills value human resources (mainly the knowledge and competences of employees and leadership skills of managers) and intangible resources (e.g., market position, organisational values, intellectual capitals, advanced technologies, and know how). Innovation and resources are very important in building the competitiveness of steel mills. In a market economy and under conditions of strong competition, innovation is understood very broadly, e.g., the implementation of new or improved products and services, better processes, new methods and techniques, new organisational and economic practices, better workplaces, and new relationships in the value chain (Popa et al. 2010). The purpose of this article is to present the path of change in the Polish steel sector from the 1990s to now. The current activities of the steel branch in the world are aimed at creating steel mills 4.0, according to the concept of Industry 4.0 (I 4.0) (Peters 2017; Zeman 2017). In 2011, Professor Henning Kagermann proposed the German term: “Industrie 4.0”. The term evolved into a strategy for the development of German industry. Industry 4.0 is, first, new technologies, such as robotics and automation, 3D printing, collaborative robots (cobots), cloud computing and the Internet of Things (IoT). Moreover, Industry 4.0 is a new paradigmatic concept of changes in factories towards smart factories in the future (Kagermann et al. 2011, 2013a, 2013b). The practical part of the chapter is divided into three parts. The first covers the period 1990 to 2000, the second from 2000 to 2010, and the third until 2020. The main aim of this chapter is a presentation of the level of digitalisation in the steel industry in Poland. At present, in Poland, the steel sector is investing more strongly in IC systems and digital technologies. Currently, Polish mills are considered to be operating as steel mills 3.0, similarly to many European steel mills (Peters 2016), and strategies moving towards Industry 4.0 have been adopted and implemented in the steel mills.

As digitisation prepares the environment for Industry 4.0, it is necessary to analyse the level of development of digital technology in separate industries in order to determine the level of maturity (Schumacher et al. 2019).

2. Background of the Topic: Innovation and Digitisation on the Way to Steel Mills 4.0

Around the world, the Fourth Industrial Revolution is underway, which is building Industry 4.0. In Industry 4.0, there will be constant communication and data exchange between sensor and sensor networks and management software throughout the entire production process, from research and product development to post-sales services. Real-time data will not only be collected, but also analysed and converted into immediate reactions that will be enacted between smart factories, products and users throughout the production chain, as well as throughout the product life cycle. Failure to implement Industry 4.0 solutions, i.e., multiple innovations and digitalisation in factories and companies, will cause the organisation to stagnate in relation to its competitors. In a market economy, companies successfully apply the latest products and IT solutions. Industry 4.0 is based on many pillars. Erboz (2017), and Burrell (2019), (as well as many other authors not cited here) have described the main pillars of Industry 4.0 in their publications. Technological innovations related to Industry 4.0 do not concern one group of technologies, but many technological solutions, referred to as technological components. The technology of Industry 4.0 consists of technologies connecting physical and digital objects, advanced network solutions, data processing technologies, and technologies relating to physical and digital processes (Culot et al. 2020). Although digitisation was one of the technical achievements of the Third Industrial Revolution, it has gained more application in the Fourth Revolution, now it is highly intelligent. The impact of digitisation is major; many companies believe it is vital to follow digitisation trends in order to stay competitive in terms of effectiveness, growth and prosperity (Vernersson et al. 2015; BCG 2017). Digitisation together with the Internet, mobile application, Industrial Internet of Things (IIoT) and services (IIoS) are building new communication environments (Wollschlaeger et al. 2017). This new digitisation is smarter and more intelligent, but as cited by Darvishi et al. (2021), many technical aspects have not yet been explored in terms of usability, e.g., sensor defect detection. Industrial digitalisation working together with Industry 4.0 technology is the basis for a mature model of manufacturing companies (Schumacher et al. 2019). According to Schumacher et al., the maturity of companies using digitalisation concerns many aspects of business, e.g., communication (Weber et al. 2017), Maintenance

4.0 (Nemeth et al. 2018), business processes (Jochem et al. 2011), Internal Logistics 4.0 and the supply chain (Klötzer and Pflaum 2017) using digital information systems (Proença and Borbinha 2016), software landscapes (Leyh et al. 2017), and big data (Comuzzi and Patel 2016). Digitalisation in manufacturing requires the use of modern production management systems and software, enabling the real-time observation of processes and immediate reactions to undesirable actions. In the steel sector, digital technologies can be applied in order to increase the flexibility and reliability of industrial processes and improve the product quality. Digital technology can also be used for monitoring and assessing the environmental performance of steel industry organisation processes improving control levels of production and of auxiliary processes that have major environmental impacts (Peters et al. 2019). Those technologies should also provide key performance indicators for resources efficiency, e.g., energy (Wolniak et al. 2020; Gajdzik and Sroka 2021). Digital business respects the principles of sustainability. The popularized concept of Industry 4.0 is based on the goals of sustainable business (Gajdzik et al. 2020). Digital technology improves operational performance and reduces process safety accidents (Lee et al. 2019). Steel mills using digitalisation can expect, similarly to other companies, benefits such as reduced resource consumption and process optimisation, shorter machine downtime and longer machine life, higher employee productivity, reduction in time between different production stages, reduction in overproduction, acceleration of R&D processes thanks to 3D printing, elimination of supply constraints, lower inventory storage costs, and better production quality (Gajdzik and Sitko 2014). Such benefits are possible because modern digitalisation solves problems and eliminates errors in real time. In today's digital economy, the link between demand and supply is better. Companies use various methods to analyse and create demand (marketing automation systems). Technology improves demand forecasting quality and reduces the time to market. With 3D printing or concurrent engineering, it is possible to prototype new products very quickly and enter the market with them. Digitisation is also a better after-sales service and service, thanks to remote servicing or guided self-service using augmented reality (more information is in the IDC report, and the report on gov.pl). Enterprises in Industry 4.0 have initiated the digitisation in manufacturing and are striving to be a part of the digital ecosystem.

3. Polish Steel Industry in the Period 1990 to 2000: A Brief Description of Difficult Ways to Market

In the first decade analysed, many quantitative changes were realised in steel mills in Poland. In 1990, the sector employed 147,000 people. In 2000, there were

38.7 thousand people employed. The reduction in employment was accompanied by a decrease in steel production, which increased productivity (amount of steel per employee). In 1990, 13.6 million tonnes of steel were produced 10.5 million tonnes of crude steel, productivity 271.3 tonnes per employee, compared to 91.9 tonnes per employee in 1990, an increase of 179.4 tonnes per employee (Gajdzik 2013). More automatic operations were introduced into the applied steel melting technology. The production lines in mills were extended with BOF technology—these were the so-called continuous casting lines (Polish abbreviation: COS). The share of this technology in the production of semi-finished steel products in the mills in the early 1990s did not exceed 5%. Expenditure on investments in technologies, products and processes in Polish steel branch in the years from 1992 to 2000 amounted to PLN 7.5 billion. At that time, many steel mills in Poland had financial debts to suppliers and organisations. These debts were repaid by, for example, selling off the steel mills’ redundant assets, in particular, non-productive assets (non-core business). In the 1990s, outsourcing activities—the separation of companies from production enterprise—intensified in Poland (Foltys 2007). Steel mills that did not achieve profitability or did not cope in the market with the new unbundled, self-managed business went bankrupt. This was the most difficult period of transition for the Polish steel sector (Pałucha 2012). Figure 1 compares the expenditure on technological investment in the Polish steel industry with productivity (amount of crude steel per employee) in the analysed period.

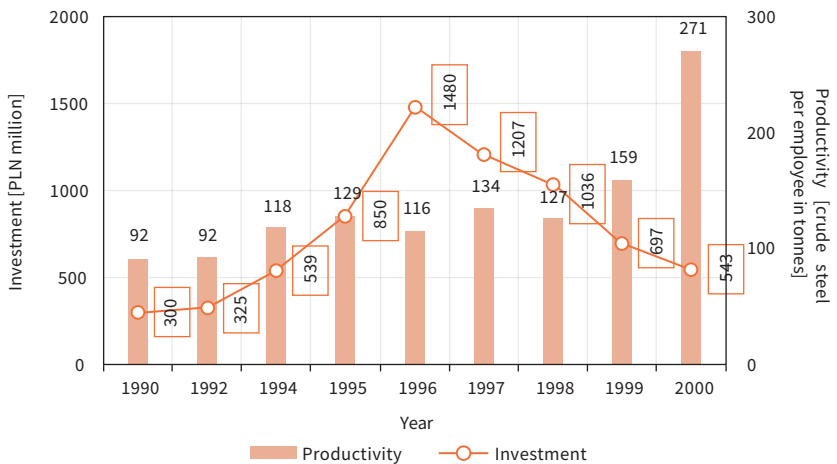


Figure 1. Investment and productivity in the Polish steel industry in the period 1990 to 2000. Source: Author’s compilation based on data from HIPH (n.d.). Reports: *Polish steel industry*.

4. Polish Steel Industry in the Period 2000 to 2010: Visible Indicators of Competitiveness

During this period, many changes were introduced to improve the competitiveness of steel plants, and foreign capital contributed to these changes. The most important event of this period was the purchase of steel plants by foreign investors. In 2004, Mittal, now ArcelorMittal, entered the Polish market (on 29 May 2007, a steel producer brand named ArcelorMittal was officially launched on the Polish market) (Ślusarczyk and Kot 2011). A year earlier (in 2003), the CMC group (Commercial Metals Company) appeared. In the same year, the Spanish Celsa acquired the Ostrowiec steel mill. Foreign capital owns the largest steel mills in Poland (Gajdzik and Sroka 2012). The open market economy with external and internal factors inspired the steel enterprises in Poland to introduce changes. The changes introduced in steel enterprises are shown in Figure 2. The main areas of change included: product range, manufacturing technology, organisation and management, and even company culture.

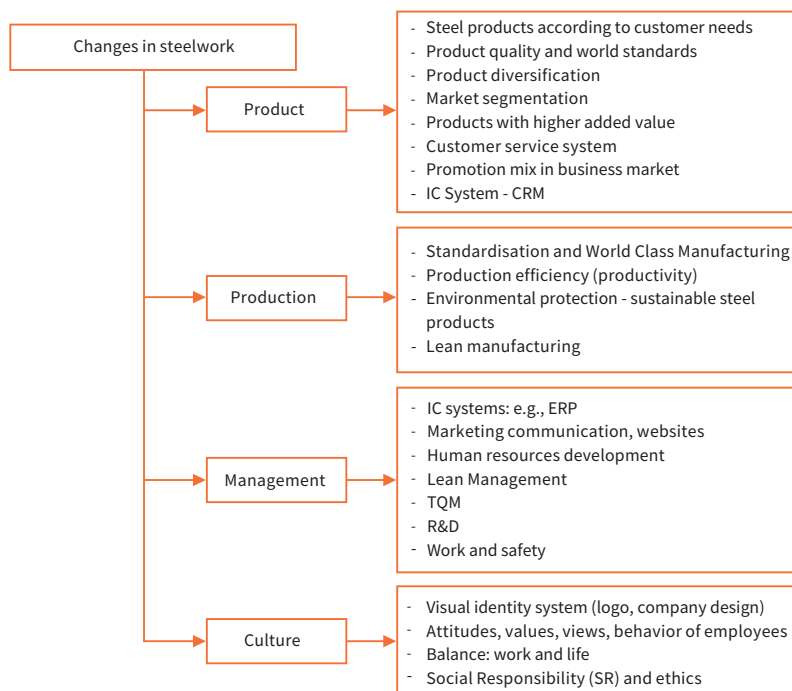


Figure 2. The key fields of changes in steel mills in Poland on their way to competitiveness. Source: Figure by author.

In 2002, the technology—created by Martin Siemens—for smelting steel in open-hearth furnaces was withdrawn. Since 2003, crude steel in Poland has been produced using only two processes: EAF and BOF. The volume of steel produced is constantly adjusted to market demand. The trend in steel production has seasonal variations (cycles). Figure 3 shows the volume of manufactured crude steel in Poland from 2000 to 2020.

In the period 2001 to 2010, investment expenditure amounted to PLN 8.8 billion. Expenditure on technological investments and process innovations resulted in an increase in labour productivity (Figure 4).

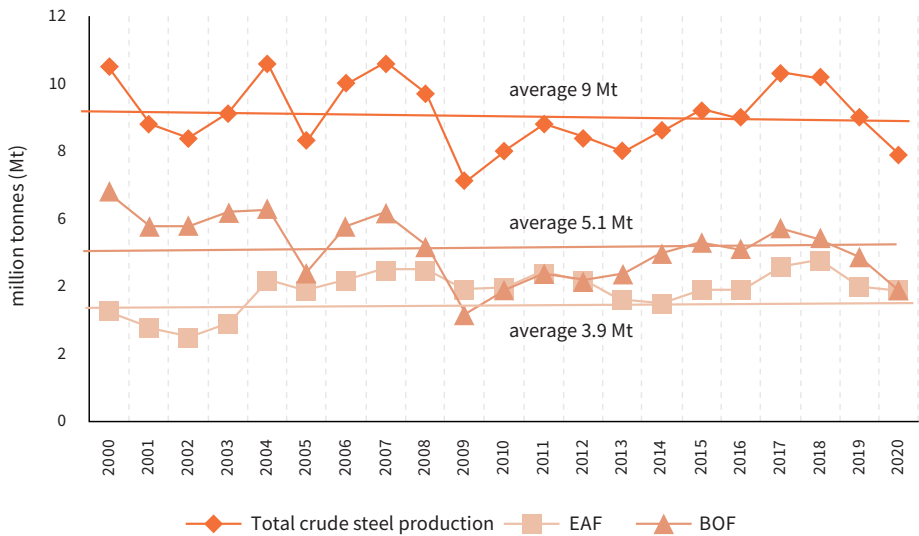


Figure 3. Manufactured crude steel in Poland in the period 2000 to 2020.
 Source: Author’s compilation based on data from yearly reports 2000–2020 (WorldSteel Association n.d.).¹

¹ Steel in figures from 2000 to 2020. Available online: <https://www.worldsteel.org/steel-by-topic/statistics/World-Steel-in-Figures.html> (accessed on 23 September 2021).

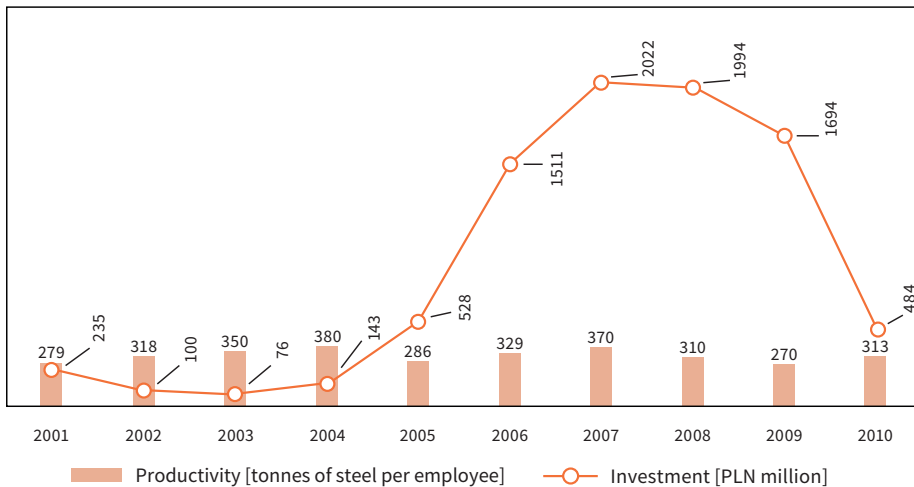


Figure 4. Investment and productivity in the Polish steel industry in the period 2001 to 2010. Source: Author’s compilation based on data from the Polish Steel Association yearly reports 2001–2010 (HIPH n.d.).²

5. Steel Industry in Poland in the Period 2010 to 2020: Innovation and Digitisation Determinants for the Strategic Direction of Steel mills 4.0

The year 2009 (two years after the global financial crisis—GFC, that started in the United States) was difficult for Polish steel mills—a drop in production (Figure 3) was caused by the global financial crisis of 2007–2008. In 2010, investment expenditures of steel mills were four times lower than in 2007 (when expenditures were the highest—Figure 4). During the crisis management period, the steel mills in Poland introduced cutting strategies (Gajdzik 2014). In investments, the increase in spending started from 2011 in the Polish steel sector (Figure 5). From 2005 to 2018, there was an increase in R&D spending (almost sixfold) (Figure 6).

² https://www.hiph.org/ANALIZY_RAPORTY/liczby.php (accessed on 29 September 2021).

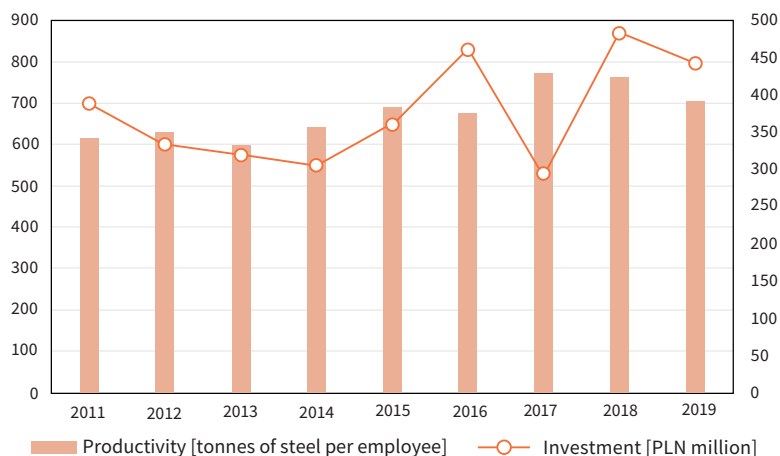


Figure 5. Investment and productivity in the Polish steel industry in 2011–2019.
Source: Author's compilation based on data from the Polish Steel Association yearly reports 2011–2019 (HIPH n.d.).

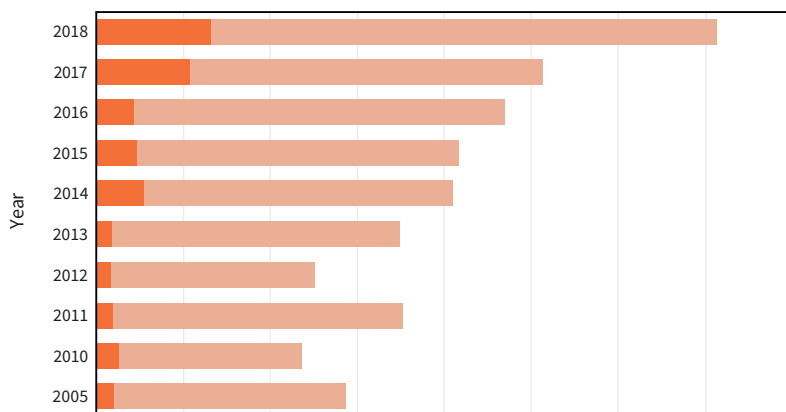


Figure 6. Expenditure on R&D and innovation in the Polish steel industry in 2005–2018.
Source: Author's compilation based on data from Statistics Poland (2020).³

³ Use of information and communication technologies in enterprises in 2020. Available online: <https://stat.gov.pl/obszary-tematyczne/nauka-i-technika-spoleczenstwo-informacyjne/spoleczenstwo-informacyjne/wykorzystanie-technologii-informacyjno-komunikacyjnych-w-jednostkach-administracji-publicznej-przedsiębiorstwach-i-gospodarstwach-domowych-w-2020-roku,3,19.html> (accessed on 23 September 2021).

Expenditure on innovation in the steel industry in Poland doubled in the period 2005 to 2018 (Figure 7). New products, processes, services have had a positive impact on the steel business in Poland. Product and process innovation are closely linked with IT. Digitalised plants use sensor technology, digital production-controlling tools and AI diagnostics to monitor smart components. Each process in the plant is continually analysed and refined for incremental improvements in efficiency. Output is optimised for maximum overall performance.

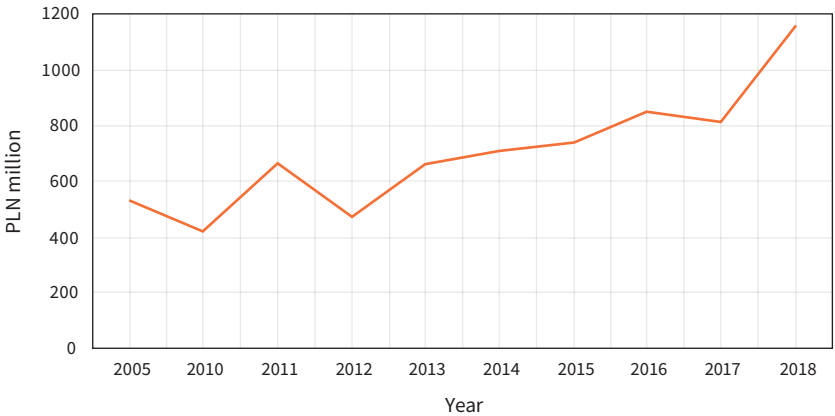


Figure 7. Expenditure on innovation in the Polish steel industry in the period 2005 to 2018. Source: Author’s compilation based on data from Statistics Poland (2020).

In the analysed period, steel mills in Poland invested heavily in digitalisation. Information and communication technologies used in the steel industry in Poland involve computers; Internet access, including broadband and mobile; companies’ own websites; e-government/administration; enterprises purchasing cloud computing services; enterprises using social media; ERP systems; and CRM systems. Based on statistical data, the usage of ICT in the steel industry is presented (Figure 8).

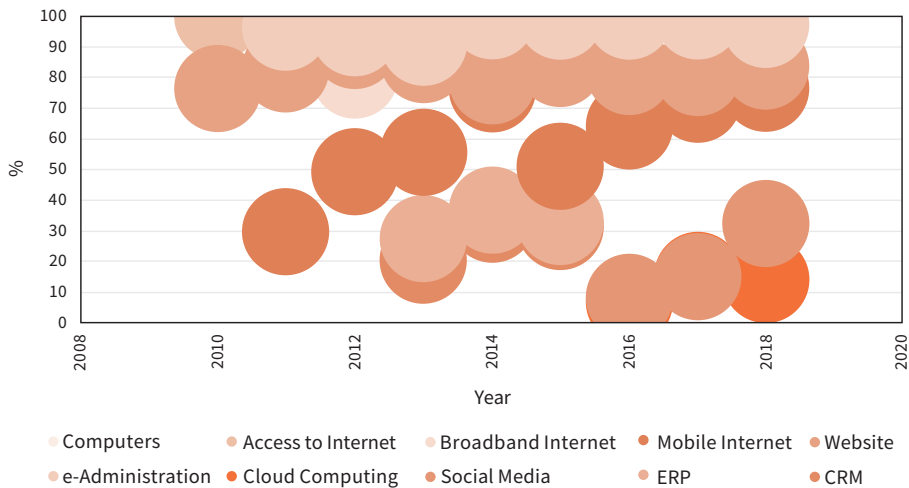


Figure 8. Use of ICT in the metal industry in Poland. Source: Author’s compilation based on data from Statistics Poland (2020).

The use of computers, e-government, collaboration and communication via the Internet, including broadband, is growing year on year in steel mills in Poland. Technological advances are boosting the efficiency in industries. Technology of the Fourth Industrial Revolution is allowing working in ever-closer harmony with different processes of steel and metal production, transforming the way steel is made. Zeman (2017) points out that the steel industry is now halfway between Steelwork 3.0 and Steelwork 4.0. The strengths of the mills of the future are: “deep” automation, digitisation, virtualisation, simulation, processing of data in real time, machine communication and artificial intelligence. Peters (2017) said that “Currently, mills are at the beginning of a long-term evolution with steelwork 3.0 to steelwork 4.0”. Progress to Steelwork 4.0 has been halted by the COVID-19 crisis. The year 2020 has been called the COVID-19 year. In 2020, the Polish industry sharply reduced its demand for steel (Gajdzik and Wolniak 2021). However, compared to 2009, the year in which the Polish steel sector was affected by the financial crisis, the decrease in steel production was smaller (Gajdzik and Wolniak 2021). At the end of 2020 (November–December), steel production in Poland increased compared to the previous year (Gajdzik 2021). The COVID-19 crisis and the downturn in the European steel market caused by the surplus of steel production (supply exceeding demand), as well as rising environmental costs (CO₂ emission reduction policy), are dampening investments by Polish steel mills. However, the strategic (long-term) direction of change—steel Industry 4.0—has been continued (fraunhofer.de 2018): the COVID-19

crisis has reinforced the steel mills’ belief that the digitisation and automation of steel production will enable them to operate through periods of face-to-face shortages and job cuts. Steel producers in Poland have been implementing digital and technological innovations for several years. Examples of activities include mobile inspections, integrated information and computer systems (SAP), remote measurement and data collection systems, computerised equipment control, 3D printing, and 3D visualisation. The varieties of applied Industry 4.0 technologies create nine pillars (Erboz 2017; Burrell 2019), and digitalisation (Kagermann 2015) enables steel mills to realise several pilot programs (start-ups) and segment the application and implementation of new techniques in the steel industry (Gajdzik et al. 2021). As well as converting traditional steel mills into highly automated “smart” plants, digitalisation enables the different parts of the manufacturing process to interact and perform at their full potential. The share of companies that systematically introduced innovative or improved products or new or improved processes reached 50% of the total number of companies in the Polish steel (metal) industry (Figure 9).

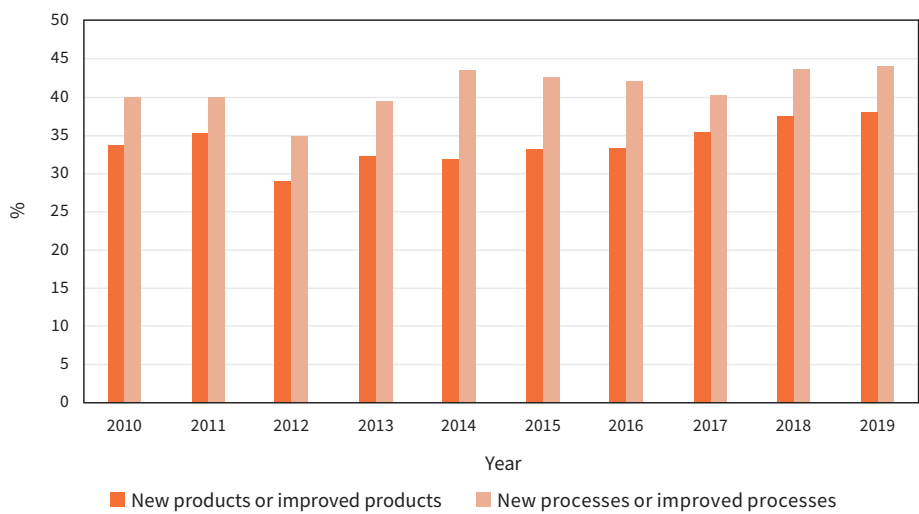


Figure 9. New and improved products or new and improved processes in the metal industry in Poland in the period 2010 to 2019. Source: Author’s compilation based on data from Statistics Poland (2020).

6. Discussion

Global industry and that in Europe are changing dynamically all the time. In Poland, we are dealing with the transformation of industry. These changes in

industry are accompanied by progressive automation and digitalisation. The steel industry in Europe and Poland plays a major role in GDP and employment. In Poland, steel industry account for about 3.5% of GDP and employ over 20,000 people. Steel production is interrelated with other market sectors. Consumers of steel include the automotive industry, construction, engineering, transport and other sectors. For every person employed in steel plants, there are four persons employed in other sectors. Annually, the Polish steel industry produces more than nine million tonnes of steel, and its capacity (production capacity) is even higher. Nowadays, digitalisation and automation are essential elements to be taken into account in business decisions. In the Polish steel market, there are strong foreign capital groups which invest in the development of steel mills. The main trend of digitalisation in metallurgy concerns the management and optimisation of production through real-time data analysis. The second trend is maintenance using data, predicting and preventing machine failures and downtime. A distinctive feature of metallurgy is the optimisation of furnace parameters, taking into account the type of material used. In Poland, just over 50% of steel is produced using BF+ BOF technology, and almost 50% is produced using EAF technology. Digitalisation used in steel melting technology optimises processes, improves steel quality and increases work safety. In Poland, significant challenges remain with the control of working time, and the introduction of digital logbooks with tasks for maintenance. An employee receives a task and reports its completion via the system, which can assess the status of work in real time and plan further activities. These are not revolutionary innovations, but they may significantly change the work environment in steel mills. Digitisation of steel production can be seen as the consistent application of new technologies to meet steelmakers' requirements for quality, flexibility and productivity (Herzog et al. 2017). Digitisation is not only a matter of purchasing new equipment, but of developing human resources. Major resources invested in the purchase of equipment, and automation, must go hand in hand with proper communication with employees and a training system in order for their potential to be fully exploited. Competencies are charisma, relationship building, curiosity about the world, openness to change, emotional intelligence, inspiring others, kindness, sense of responsibility, quality orientation, and digital agility. Machines take over repetitive activities, so that work loses its routine character, and the tasks of workers progress to problem-solving, designing, communicating and interpreting information (Romero et al. 2016; Ruppert et al. 2018). Digitalisation in Industry 4.0 creates new challenges for leaders. Leaders 4.0 need to be more flexible and open to working with employees (Oosthuizen 2017). The staff in steel mills in Poland need to be rejuvenated. There is a generation gap in large

steel mills in Poland—there are more employees aged over 45 than young people (Gajdzik and Szymshal 2015).

The future of digitalisation in steel mills will primarily be sustainable production. Important environmental aspects of steel mills are reduced energy consumption (renewable electricity) and the reduction in CO₂ emissions (e.g., capturing CO₂ from BF and converting it into hot reducing gas). Sustainability is strongly linked to Industry 4.0, especially in the context of the green economy. Investments are being made in research and development that will, in future, enable steel mills not to use fossil fuels, but to use hydrogen instead of coke, for example. Decarbonised steel production on a mass scale is a challenge for the steel industry. New steel production processes will create new areas for digitisation in steel mills.

7. Conclusions

Research has shown that technological investments and the use of ICT, R&D, and improved products and processes foster innovation in the Polish steel industry. However, these are fragmented studies, limited to statistical summaries. There has been no analysis simultaneously covering all the issues of innovativeness of the Polish steel industry in order to answer the question about the readiness of steel mills in Poland for Industry 4.0. The three periods of analysis used in this paper show the transformation of the steel industry. There were state-owned steel plants in a centrally managed economy; now, their owners are capital investors, and plants realise their business in markets. Steel mills in Poland, through many years of investment, have become able to set the course for development as steel mills 4.0. In line with the aim of the analysis and on the basis of statistical data, a conclusion has been drawn that steel mills in Poland should build an environment for Industry 4.0.

The application of digital technology in Industry 4.0 is very broad. The baseline stage is the digitisation of production. The next steps are the construction of a digital environment for the consumer and supplier. Additionally, the final solution is a digital ecosystem with interfaces for suppliers, partners and customers; the product will be embedded in an ecosystem for co-creation and additional new value capture. The entry of digitalisation into the new technology environment of Industry 4.0 requires investments. The existing technologies give way to new ones, which are promoted in the Fourth Industrial Revolution.

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