CHANGES IN THE LABOUR PRODUCTIVITY AND EFFICIENCY OF METAL INDUSTRY IN POLAND

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Abstract

The article presents efficiency and labour productivity analysis of Polish metal industry in 2010-2014. The main purpose of this paper is to compare the efficiency of 12 branch manufacturing metal products in Poland. The study applies the Malmquist Productivity Index (MPI), which was used to analyze changes in metal industry productivity. The study indicated which factor - technological progress or changes in technical efficiency had a greater impact on the change in productivity of metal industry in Poland. Meanwhile, the highest average index of changes in MPI during the period was achieved by manufacture of basic iron and steel and of ferroalloys and manufacture of basic precious and other non-ferrous metals.

Keywords: Efficiency, labour productivity, metal industry, malmquist productivity index

1. INTRODUCTION

Iron and steel metallurgy, as well as non-ferrous metal metallurgy is one of two (aside from the mining of metal ores) major parts of the metallurgical industry. In Poland, steel is one of the basic construction materials - both in construction and in manufacturing. In 2011, Poland produced 8.8 million tons of crude steel, accounting for 0.6% of world production (Poland ranks 8th in Europe and 19th in the world). Currently no iron ore mining activities are conducted in Poland [1]. Polish mills base their production on imported raw materials - for example, from the Kryvyi Rih region in Ukraine. The largest mills in the country are Huta Katowice [Katowice steel mill] in Dąbrowa Górnicza and Huta im. T. Sendzimira [T. Sendzimir steel mill] in Nowa Huta in Cracow (and mills in Sosnowiec and Świętochłowice) that form part of the Polskie Huty Stali [Polish Steel Mills] group currently owned by the metallurgical giant - Arcelor-Mittal, which account for 70% of steel produced in Poland.

In turn, copper smelting in Poland focuses primarily in the Legnicko-Głogowski Okręg Miedziowy (LGOM) [Legnica-Głogów Copper District]. In 2011, Poland produced 594 thousand tonnes, which represents 3% of world production (Poland ranks 3rd in Europe and 9th in the world) [1].

Zinc and lead smelters are located, in turn, in Upper Silesia, a region where zinc and lead ores are extracted. In 2011, the smelters produced 109 thousand tonnes of zinc, which represents 1% of world production.

When Poland was on the verge of the political transformation, Polish metallurgy faced the need to restructure 26 metallurgical plants with a total production capacity of about 20 million tonnes of crude steel per year, far exceeding the needs of the domestic market. A big challenge for the industry was not only excess production capacity, but also obsolete equipment, a still high share of open-hearth steel, high rate of steel cast into ingot molds (93%), overstaffing and low productivity. The restructuring costs were estimated at PLN 12 billion and were incurred mainly by the mills themselves, which led to the companies going into significant debt. Due to Poland's efforts to join the European Union, the metallurgical industry could not benefit from public aid beyond the restructuring support in the amount of PLN 3.4 billion, negotiated and entered in Protocol 8 of the Accession Treaty [2, 3].

The restructuring process in the steel sector ended in 2006, leaving modernized plants with a production capacity of 12.6 million tonnes and production exceeding 10 million tonnes. The metallurgical industry was completely privatized, production of steel in open-hearth furnaces stopped and the share of continuous steel casting increased from 7 to 82% [2]. The basic oxygen process increased its share in steel production to approximately 60% (**Figure 1**).

Restructuring has allowed the Polish steel industry to compete at an international level in terms of technology, but the dynamically changing economic and legal environment poses ever new challenges for steel manufacturers. The high cost of energy and raw materials for steel production, as well as EU requirements for reducing the impact of the industry on the environment have necessitated further investments to improve the competitiveness of the metallurgical plants [4, 5, 6]. In the years 2004-2013 the mills allocated approximately PLN 10 billion for new investments and the necessary upgrades [2].

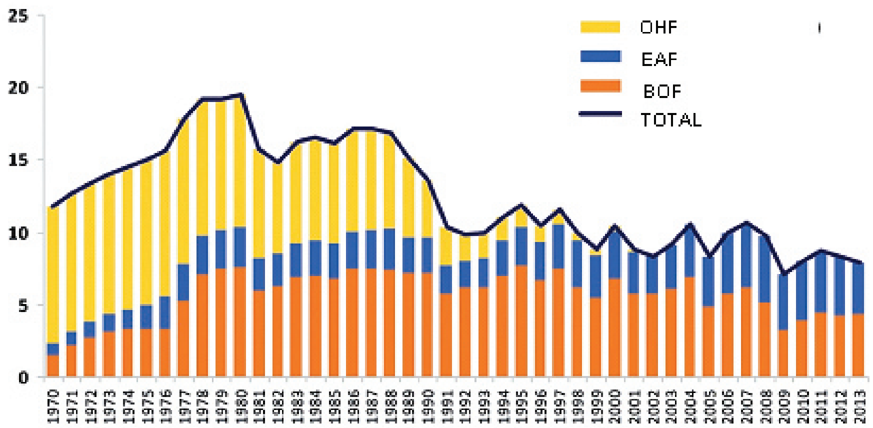

Figure 1 Structure of crude steel production in Poland with a breakdown into processes in the years 1970-2013 [in millions of tonnes]

Source: [2]

Despite the high level of technological advancement the domestic steel industry has over the past few years faced the problem of redundant production capacity. In 2013, with a level of production of 8 million tonnes, only 63% of the production capacity was used. For comparison, the same indicator for the world overall amounted to 74% and for the whole EU to 71% [2]. In order for the Polish metallurgical sector to be even more competitive, both in relation to third countries, as well as competitors from the European Union, it is necessary to create a multi-faceted policy with respect to the metallurgical industry [7]. A regulatory framework has to be introduced to allow the steel industry to achieve sustainable development, conduct activities aimed at increasing demand for steel products, facilitate steel producers' access to foreign markets, secure affordable energy prices and mitigate the impact of the energy and raw material policy on production costs, as well as to promote innovation and the development of skills of those employed in the metallurgical industry. Continuous monitoring of the efficiency and productivity of the sector is needed both within (between particular metallurgical industry sectors), as well as outside - against other metallurgical sectors in the world [8, 9].

The purpose of this article was to evaluate efficiency and changes in the productivity of individual sectors of the metallurgical industry in Poland in 2010-2014, as well as to indicate how technical efficiency of the industries and technological progress shaped. The studies were based on the Malmquist Productivity Index.

2. THE METHODOLOGY OF MALMQUIST PRODUCTIVITY INDEX

The Malmquist Productivity Index (MPI) was employed in order to verify the research hypotheses on the basis of data for the metal industry in US. Malmquist Productivity Index is the most frequently used approach to quantification of changes in total factor productivity. MPI first introduced by Malmquist [10] has further been studied and developed in Färe et al. [11; 12]. Färe et al. [11] constructed the DEA-based MPI as the geometric mean of the two Malmquist productivity indices of Caves et al. [13] - one measures the change in technical efficiency and the other measures the shift in the frontier technology. Färe et al. [12] developed it into the output-based Malmquist productivity change index. The input-oriented Malmquist productivity index of a DMU can be expressed as

$$M(y_{t+1}, x_{t+1}, y_t, x_t) = \left[\frac{D^t(y_{t+1}, x_{t+1})}{D^t(y_t, x_t)} x \frac{D^{t+1}(y_{t+1}, x_{t+1})}{D^{t+1}(y_t, x_t)} \right]^{\frac{1}{2}} \quad (1)$$

where x_t and x_{t+1} are input vectors of dimension l at time t and $t+1$, respectively. y_t and y_{t+1} are the corresponding k-output vectors. D^t and D^{t+1} denote an input - oriented distance function with respect to production technology at t or $t+1$, which is defined as:

$$D(x, y) = \max\{\rho : (s/\rho) \in L(y)\} \quad (2)$$

where $L(y)$ represents the number of all input vectors with which a certain output vector y can be produced, that is, $L(y)=\{x: y \text{ can be produced with } x\}$. ρ in eq. (2) can be understood as a reciprocal value of the factor by with the total inputs could be maximally reduced without reducing output.

M measures the productivity change between periods t and $t + 1$, productivity declines if $M < 1$, remains unchanged if $M = 1$ and improves if $M > 1$. The frontier technology determined by the efficient frontier is estimated using DEA for a set of DMUs. However, the frontier technology for a particular DMU under evaluation is only represented by a section of the DEA frontier or a facet. Färe et al. [11] decomposed the MPI in eq. (1) into two terms, as shown in eq. (3), that makes it possible to measure the change of technical efficiency and the shift of the frontier in terms of a specific DMU. This implies that productivity change includes changes in technical efficiency (EFCH) as well as changes in production technology (technical change TECH).

$$M(y_{t+1}, x_{t+1}, y_t, x_t) = \underbrace{\frac{D^t(y_{t+1}, x_{t+1})}{D^t(y_t, x_t)}}_{EFCH^{t+1}} x \underbrace{\left[\frac{D^t(y_{t+1}, x_{t+1})}{D^{t+1}(y_{t+1}, x_{t+1})} x \frac{D^t(y_t, x_t)}{D^{t+1}(y_t, x_t)} \right]^{\frac{1}{2}}}_{TECH^{t+1}} \quad (3)$$

The first term on the left hand side captures the change in technical efficiency (EFCH) between periods t and $t + 1$. EFCH > 1 indicates that technical efficiency change improves while EFCH <1 indicates efficiency change declines. The second term measures the technology frontier shift (TECH) between periods t and $t + 1$. A value of TECH >1 indicates progress in the technology, a value of TECH < 1 indicates regress in the technology. TECH = 1 indicates no shift in technology frontier. The technical efficiency change can further be decomposed into scale efficiency change (SECH) and pure technical efficiency change (PTEC) [10].

3. RESULTS

The studies undertaken cover the Polish metal manufacturing sectors in years 2010-2014. The study was based on source data collected in the Central Statistical Office data regarding the following metal manufacturing sectors in Poland:

- manufacture of basic iron and steel and of ferroalloys,
- manufacture of tubes, pipes, hollow profiles and related fittings, of steel,
- manufacture of other products of first processing of steel,
- manufacture of basic precious and other non-ferrous metals,
- casting of metals,
- manufacture of structural metal products,
- manufacture of tanks, reservoirs and containers of metal,
- manufacture of steam generators, except central heating hot water boilers,

- manufacture of weapons and ammunition,
- forging, pressing, stamping and roll- forming of metal; powder metallurgy,
- treatment and coating of metals; machining,
- manufacture of cutlery, tools and general hardware.

Since Poland's accession to the EU the metallurgical sector has seen a reduction in employment, which is the result of closures of excessive and unprofitable production capacity and the need to raise productivity in order to compete with the European industry [14]. Significant differences in labour productivity can be observed when particular sectors of the metallurgical industry are considered. Sectors significantly differing in terms of labour productivity are the manufacture of basic iron and steel and of ferroalloys, as well as the manufacture of basic precious and other non-ferrous metals (**Figure 2**).

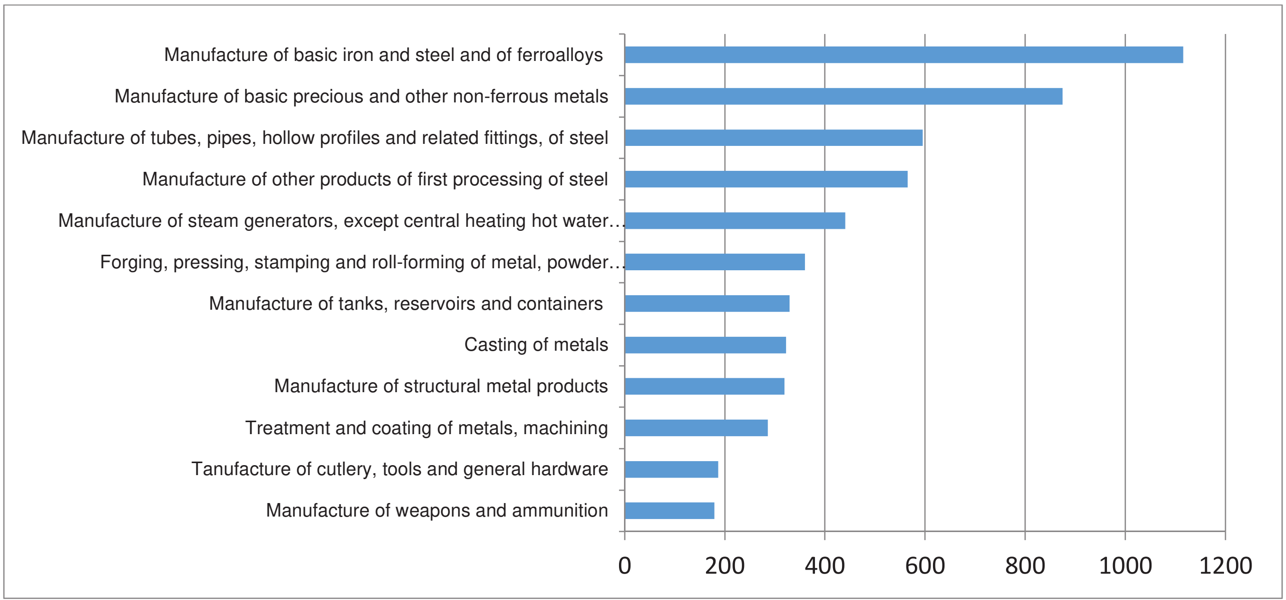

Figure 2 Labour productivity

Source: Own calculations

However, when taking into account indicators for productivity of fixed assets, the sector ranking is different. For example, the manufacture of basic iron and steel and of ferroalloys sector exhibits the highest labour productivity, but the productivity of fixed assets is significantly below the average for the metal industry (**Figure 3**). There is the problem of deciding, which of the surveyed sectors is more effective - does higher labour productivity compensate for the lower productivity of fixed assets? Therefore, the MPI index was used for the studies, which is a multi-dimensional indicator and can be used as the basis for creating a ranking of industries on the basis of a synthetic index depicting changes in productivity of sectors over time [15, 16, 17]. In order to determine factors for changes in total productivity of Polish metal industry, the Malmquist Productivity Index was used. The calculated model uses the following variables:

- effect y_1 - value of production sold by the individual branches,
- input x_1 - number of employees,
- input x_2 - fixed assets gross value.

The average annual Malmquist Productivity Index for the metallurgical industry in Poland for the years 2010-2014 ranged from 1.09 to 0.95. The highest average annual changes in productivity in the sector was recorded at the turn of 2010/2011 (**Figure 4**). In the next two periods, the sector was characterised by a decline in average productivity (MPI<1) and only between 2013 and 2014 one can assume that the average annual productivity improved slightly.

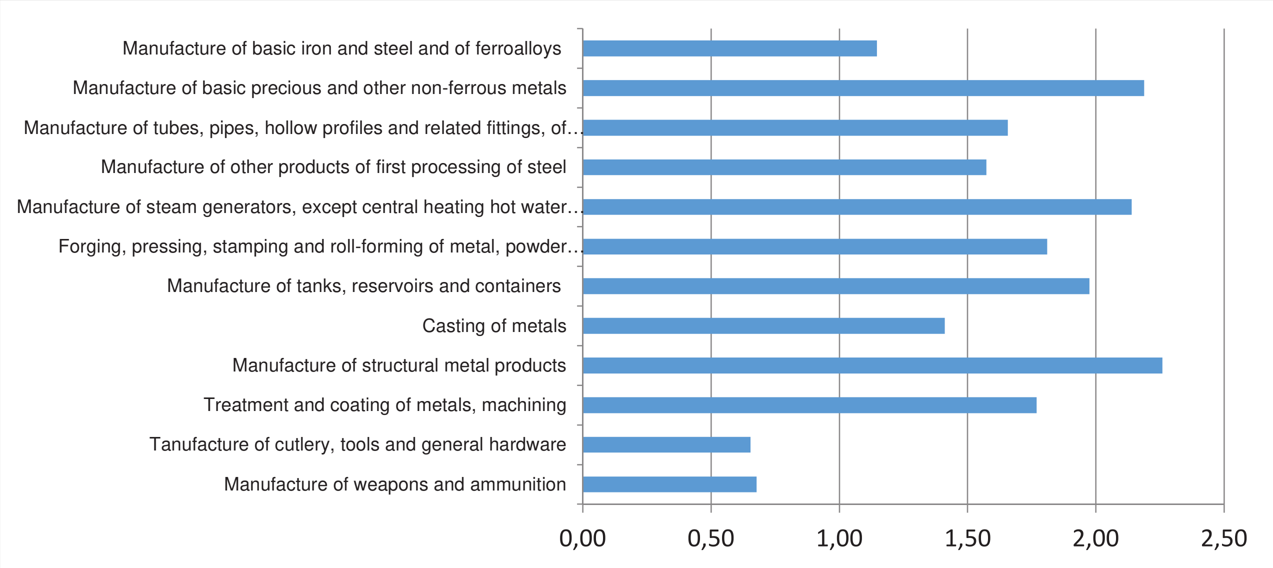

Figure 3 Productivity of fixed assets

Source: Own calculations

Taking into account the individual components of the MPI index one can observe that changes in technical efficiency (EFCH) were similar to changes for the entire MPI index. Only in the 2010/2011 period had the sector experienced improvement in efficiency, in the following years no improvement in technical efficiency was observed from period to period (**Figure 4**). Meanwhile, the average annual change in technological progress in the years 2010-2013 was at a level of 1-2% and in subsequent years no such changes were registered (the TECH indicator stood at 1).

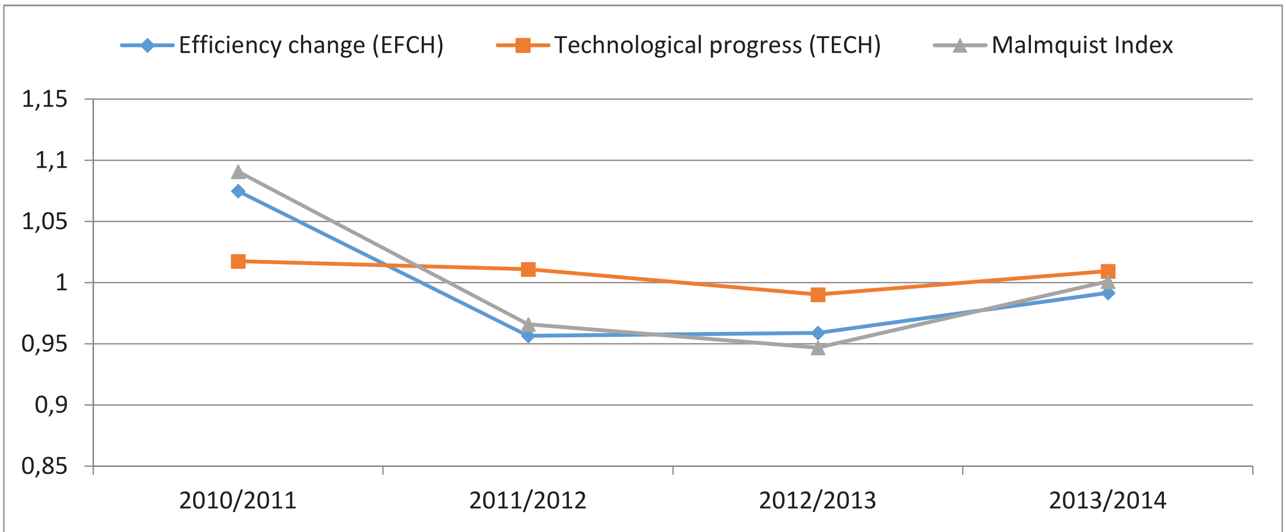

Figure 4 Malmquist Productivity Index, changes in technical efficiency, changes in production technology calculated for metal industry in US

Source: Own calculations

When analysing the average level of the Malmquist Index (MPI) in individual sectors one should consider that respectively, 4 out of the 12 sectors improved overall productivity over the studied period. The highest average annual increase in productivity was recorded in the following sectors: manufacture of basic iron and steel and of ferroalloys (9%), manufacture of basic precious and other non-ferrous metals (9%), manufacture of tanks, reservoirs and containers of metal (2.9%) and manufacture of structural metal products (2.2%), with the lowest in manufacture of weapons and ammunition (**Figure 5**).

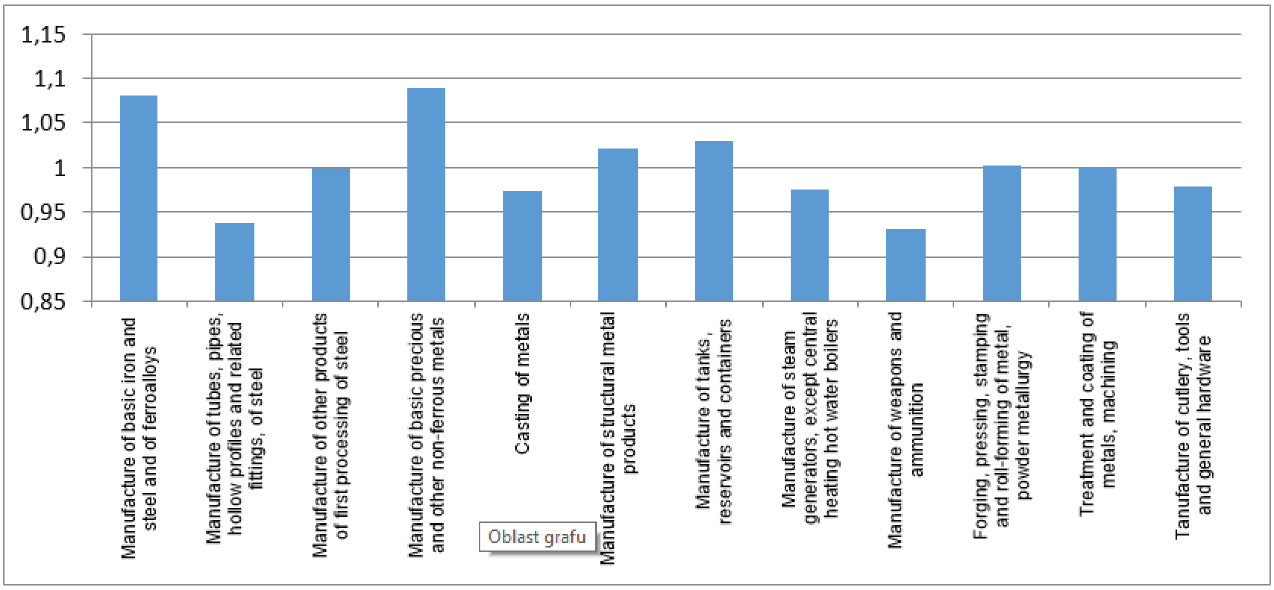

Figure 5 Average annual Malmquist Productivity Index (MPI) calculated for sectors
Source: Own calculations

The highest average indices of changes in technical efficiency (EFCH) were recorded in manufacture of basic precious and other non-ferrous metals (1.05) and manufacture of structural metal products (1.05). In turn, the lowest (less than 1) annual average indices of changes in efficiency were observed in manufacture of tubes, pipes, hollow profiles and related fittings, of steel, manufacture of other products of first processing of steel, casting of metals, manufacture of steam generators, except central heating hot water boilers, manufacture of weapons and ammunition, manufacture of cutlery, tools and general hardware (**Figure 6**).

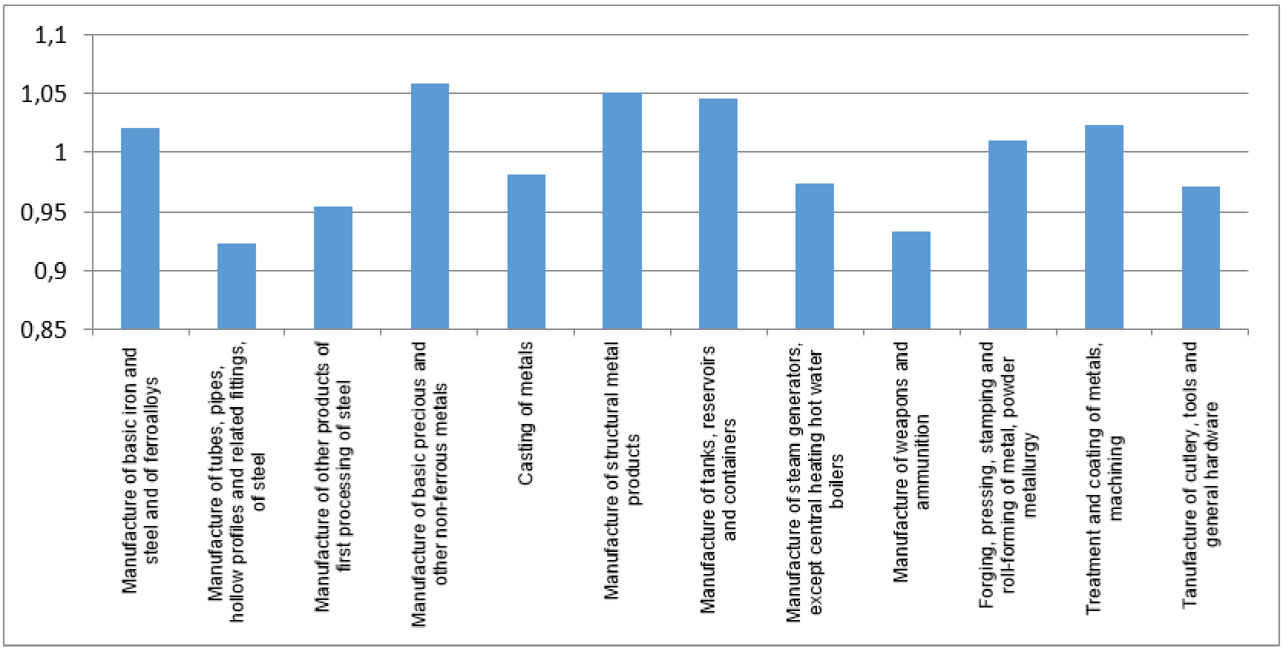

Figure 6 Changes in technical efficiency (EFCH) for sectors
Source: Own calculations

The largest average annual increases in the index of technological change (TECH) were recorded in manufacture of basic iron and steel and of ferroalloys (5.3%), manufacture of other products of first processing of steel (4.8%) (**Figure 7**). In 7 out of the 12 sectors decreased index of technological change over the studied period.

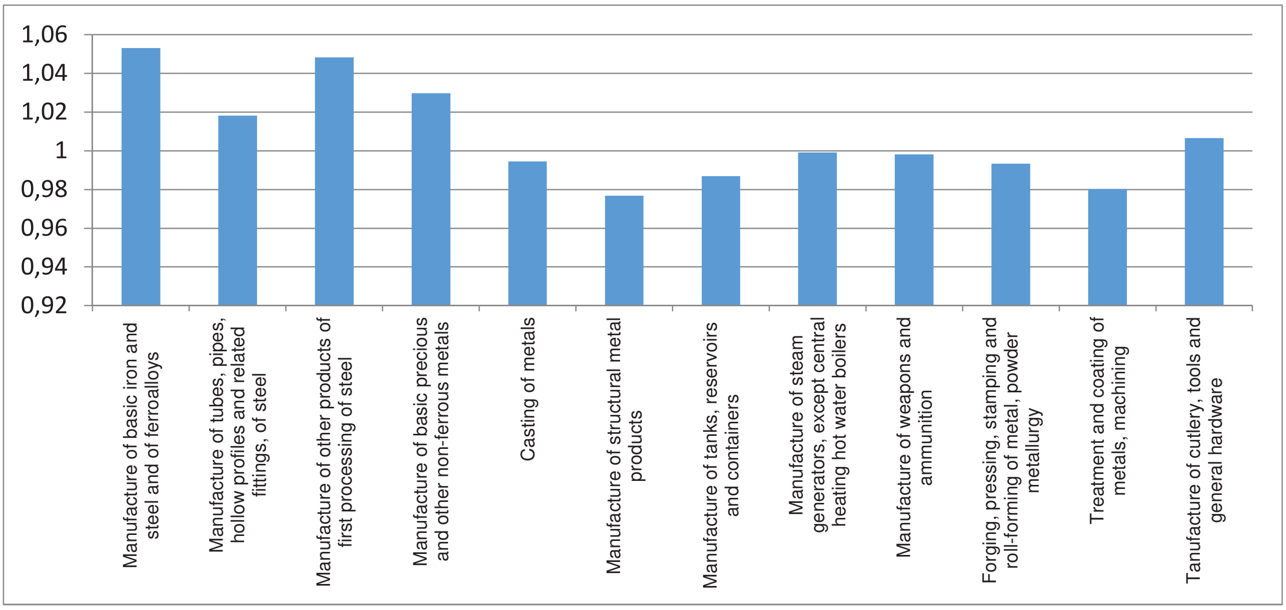

Figure 7 Changes in production technology (TECH) for sectors

Source: Own calculations

4. CONCLUSIONS

In the article, the labour efficiency and productivity of the metallurgical sector in Poland were assessed. The study found that individual metallurgical industry sectors are characterized by different levels of labour efficiency and productivity of fixed assets. It has been decided that it will be difficult to create a reliable ranking of industries according to their effectiveness, using one-dimensional indicators. For that reason further studies used the Malmquist Productivity Index. Using MPI the average annual changes in productivity for the entire metallurgical industry and particular sectors have been determined.

Considering the metallurgical sector as a whole, one can consider that only at the turn of 2010/2011 has an improvement in productivity been recorded. In subsequent years, the productivity did not improve and one can assume that it was dictated by the technical efficiency of the sector, which was characterized by deterioration. In terms of technical progress no significant changes were observed in the Polish metallurgical sector.

Within the different sectors, the highest improvement in productivity (annual average approx. 9%) was recorded in the manufacture of basic iron and steel and of ferroalloys, as well as manufacture of basic precious and other non-ferrous metals [18, 19].

In conclusion, it is worth noting that the Polish metallurgical industry is on par with the foreign competition in terms of technological development. Therefore, in order for it to improve its position on the international market, more emphasis should be put on improving technical efficiency, actions taken to increase demand for steel products, access of steel manufacturers to foreign markets made easier, as well as affordable energy prices assured and the impacts of energy and raw materials on costs of production mitigated.

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