ECONOMIC RESULTS OF THE METALLURGICAL SECTOR IN POLAND IN 2010-2016

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Abstract

The article presents efficiency and labour productivity analysis of Polish metal industry in 2010-2016. 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. The main purpose of this paper is to evaluate changes in the productivity of the metallurgical industry in Poland and to compare the efficiency of 12 branch manufacturing metal products. Meanwhile, the highest average index of changes in MPI during the period was achieved by manufacture of basic precious and other non-ferrous metals and manufacture of structural metal products.

Keywords: Metallurgy, productivity, Malmquist Productivity Index

1. INTRODUCTION

The metallurgical industry in Poland is an important branch of the economy, which is proven by its 10 percent share in sold production of general industry in 2016. There are about 1400 companies (with over 49 employees) in the field of metals and metal products production present on the Polish market [1,2].

Efficiency is the main criterion for comprehensive assessment of activities of entire industry sector and individual economic operators [3]. A micro-economic approach to efficiency is linked to individual enterprise and defined as the relation between the effects obtained by a particular economic operator and its input [4]. Efficiency of industry sectors is a very complex economic issue and methods used in the process of its analysis have their respective advantages and limitations. The integrated approach must be used - based on various methods that implement each other and therefore allow for formulation of even more credible conclusions [5,6].

The purpose of this article was to evaluate efficiency and changes in the productivity of the metallurgical industry in Poland in 2010-2016. The studies were based on the two partial productivity measures. First were labour and assets productivity, the other was Malmquist Productivity Index.

2. METHODS

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 [7] has further been studied and developed in Färe et al. [8, 9]. Färe et al. [8] constructed the DEA-based MPI as the geometric mean of the two Malmquist productivity indices of Caves et al. [10] - one measures the change in technical efficiency and the other measures the shift in the frontier technology. Färe et al. [9] developed it into the output-based Malmquist productivity change index. The input-oriented Malmquist productivity index of a DMU can be expressed as

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

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, $L(y)=\{x: y\ can\ be\ produced\ with\ x\}$. 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. [8] 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).

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

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) [7].

3. RESULTS

The research used data for 2010 − 2016 on 12 Polish sectors of the metal industry published in the Central Statistical Office. The author identified two groups of branches:

- manufacture of basic metals:
  - 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 metal products:
  - 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.

In the years 2010-2016, the number of enterprises involved in the manufacture of basic metals and metal products increased by 21% (from 1183 to 1426). During this period, the metallurgical industry also generated

an increase in sales revenue by 42%. ¾ employed in the industry engaged in the manufacture of metal products. In the analyzed period, the number of employees increased by 17% (**Table 1**).

One of the most important efficiency indicators is labour productivity. The Polish metal industry recorded in 2010-2016 an increase in labor productivity and a decrease in asset productivity (**Table 1**). Branches of the manufacture of basic metals reported annual labour productivity at PLN 740 per person. Such labour productivity was ca. 40% higher than in the sectors manufacture of metal products (**Table 1**). On the other hand, the branches manufacture of metal products experienced a higher productivity of fixed assets than manufacture of basic metal, 1.74 and 1.40 respectively. Therefore, one can question in the manufacture of metal products sectors are indeed more efficient − does their higher labour productivity compensate for their lower fixed asset productivity?

Table 1 Economic results of the metallurgical sectors in Poland

Sectors	2010	2011	2012	2013	2014	2015	2016	Dynamics 2010=100
Economic entities								
Manufacture of basic metals	160	166	172	170	171	179	190	119%
Manufacture of metal products	1023	1105	1124	1115	1142	1184	1236	121%
Metal industry (Total)	1183	1271	1296	1285	1313	1363	1426	121%
Sold production (in mln PLN)								
Manufacture of basic metals	33983	43727	42960	39318	41251	42327	42107	124%
Manufacture of metal products	39814	49344	51831	51785	55510	59011	62331	157%
Metal industry (Total)	73797	93071	94791	91103	96760	101338	104439	142%
Average paid employment (in thous)								
Manufacture of basic metals	54.6	55.4	55.5	53.7	53.6	55.0	57.9	106%
Manufacture of metal products	154.6	166.4	168.0	166.8	173.4	178.7	186.8	121%
Metal industry (Total)	209.2	221.8	223.5	220.5	227.0	233.7	244.7	117%
Labour productivity (thous PLN/person)								
Manufacture of basic metals	622	789	774	732	770	770	727	117%
Manufacture of metal products	258	297	309	310	320	330	334	130%
Metal industry (Total)	353	420	424	413	426	434	427	121%
Productivity of fixed assets								
Manufacture of basic metals	1.41	1.58	1.52	1.37	1.36	1.33	1.24	88%
Manufacture of metal products	1.73	1.88	1.83	1.73	1.75	1.67	1.60	92%
Metal industry (Total)	1.57	1.73	1.67	1.55	1.56	1.51	1,43	92%

Source: Own calculations based on Central Statistical Office 2011-2017

Considering the above issue, the authors also made a comparison on the basis of a multi-dimensional method of measuring productivity. Therefore, 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 2010-2016 ranged from 0.90 to 1.11. The highest average annual changes in productivity in the sector was recorded at the turn of 2010/2011 (**Table 2**). 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. Unfortunately, in 2014-2016, MPI was again below 1, both in the sector manufactureof basic metals and sectors manufacture of metal products.

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 and 2013/2014 periods had the sector experienced improvement in efficiency, in the following years no improvement in technical efficiency was observed from period to period (**Table 2**). Meanwhile, the average annual change in technological progress in sectors manufacture of basic metal was higher than in the sectors manufacture of metal products (the average TECH indicator was 1.01).

Table 2 Malmquist Productivity Index, changes in technical efficiency, changes in production technology calculated for metal industry in Poland

Sectors	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016	Dynamics 2010=100
Malmquist Productivity Index (MPI)							
Manufacture of basic metals	1.23	0.91	0.95	1.00	0.98	0.93	76%
Manufacture of metal products	1.12	0.94	0.90	1.01	0.97	0.91	81%
Metal industry (Total)	1.11	0.95	0.90	1.01	0.97	0.90	81%
Changes in technical efficiency (EFCH)							
Manufacture of basic metals	1.20	0.91	0.94	1.00	0.97	0.96	80%
Manufacture of metal products	1.19	0.98	0.91	1.12	0.98	0.91	76%
Metal industry (Total)	1.19	0.98	0.91	1.12	0.98	0.90	76%
Technological progres (TECH)							
Manufacture of basic metals	1.07	1.01	1.01	1.00	1.01	0.97	91%
Manufacture of metal products	1.00	0.97	0.99	0.96	1.00	1.01	100%
Metal industry (Total)	1.00	0.97	0.99	0.95	0.99	1.01	101%

Source: Own calculations based on Central Statistical Office 2011-2017

When analysing the average level of efficiency indicators in individual sectors one should consider that the highest average labour productivity was recorded in manufacture of basic iron and steel and of ferro-alloys (**Table 3**). On the other hand, the highest average productivity of fixed assets was recorded in manufacture of steam generators, except central heating hot water boilers. Respectively, 2 out of the 12 sectors improved overall productivity over the studied period (**Table 3**). The highest average annual increase in the Malmquist Index (MPI) was recorded in the following sectors: manufacture of basic precious and other non-ferrous metals (6%) and manufacture of structural metal products (4%), with the lowest in manufacture of weapons and ammunition (**Table 3**).

The average annual increases in changes in technical efficiency (EFCH) were recorded in manufacture of weapons and ammunition (1.25), manufacture of tubes, pipes, hollow profiles and related fittings, of steel (1.04), manufacture of basic precious and other non-ferrous metals (1.04) and manufacture of structural metal products (1.02). In turn, other sectors recorded a decrease in technical efficiency over the studied period.

The largest average annual increases in the index of technological change (TECH) were recorded in manufacture of basic precious and other non-ferrous metals, manufacture of structural metal products and manufacture of cutlery, tools and general hardware. In 5 out of the 12 sectors decreased index of technological change over the studied period.

Table 3 Labour productivity, productivity of fixed assets and Malmquist Productivity Index of branches manufacture of basic metals and metal products

Sectors	Labour productivity			Productivity of fixed assets			Average annual Malmquist Productivity Index (MPI) 2010-2016
	2010	2016	Dynamics 2010=100	2010	2016	Dynamics 2010=100	
Manufacture of basic metals							
manufacture of basic iron and steel and of ferro-alloys	838	1053	126%	1.23	0.97	78%	0.99
manufacture of tubes, pipes, hollow profiles and related fittings, of steel	464	561	121%	2.24	1.57	70%	0.99
manufacture of other products of first processing of steel	589	610	104%	1.59	1.48	93%	0.98
manufacture of basic precious and other non-ferrous metals	697	864	124%	1.78	2.12	119%	1.06
casting of metals	275	351	128%	1.66	1.33	80%	0.98
Manufacture of metal products							
manufacture of structural metal products	243	333	137%	2.13	1.97	92%	1.04
manufacture of tanks, reservoirs and containers of metal	263	337	128%	1.84	1.62	88%	1.00
manufacture of steam generators, except central heating hot water boilers	343	557	162%	2.47	2.48	100%	0.98
manufacture of weapons and ammunition	183	237	130%	0.93	0.85	91%	0.72
forging, pressing, stamping and roll-forming of metal; powder metallurgy	329	428	130%	1.82	1.79	99%	0.97
treatment and coating of metals; machining	240	286	119%	1.84	1.67	91%	1.00
manufacture of cutlery, tools and general hardware	157	194	124%	0.74	0.65	88%	0.98

Source: Own calculations based on Central Statistical Office 2011-2017

4. CONCLUSION

The analyses conducted in this article can be used to draw the following conclusions:

1) The paper presents an analysis of changes in efficiency and productivity of the Polish metallurgical sector in the years 2010-2016 based on labour and assets productivity and also the Malmquist Productivity Index. Results made it possible to identify the general trend for changes in productivity for the entire metal sector and its individual branches.
2) In the period between 2010 and 2016, productivity of the Polish metallurgical sector was decresing. The mean annual MPI for the analysed period was below 1, showing approx. 3% mean annual decrease in

productivity for the whole sector. In turn, between individual periods productivity was found both to increase and decrease.

3) 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.
4) The highest improvement in productivity was recorded in the manufacture of basic precious and other non-ferrous metals (annual average approx. 6%) as well as manufacture of structural metal products (annual average approx. 4%).
5) 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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