PRODUCTIVITY AND EFFICIENCY OF US METAL INDUSTRY IN 2006-2014

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Abstract

The article presents efficiency and productivity analysis of US metal industry in 2006-2014. The main purpose of this paper is to compare the efficiency of 6 sectors manufacturing metal products in US. The study applies the Malmquist Productivity Index (MPI), which was used to analyze changes in metal industry productivity. The study indicated that technological progress had a greater impact on the change in productivity of metal industry in US than changes in technical efficiency. Meanwhile, the highest average index of changes in MPI during the period was achieved by metal pipe and tube manufacturing.

Keywords: Efficiency, productivity, metal industry, Malmquist Productivity Index

1. INTRODUCTION

The global metal industry experienced a robust growth during 2008-2012 but is expected to slow down, and the industry revenue is forecast to reach an estimated $2.374 billion in 2017 with a CAGR of 5.5% over the years 2012-2017 [1].The metal industry consists of establishments primarily engaged in manufacturing all types of metals such as iron and steel, aluminium, base metals, and precious metals [2]. The industry sells a variety of products, but revenue is predominantly generated from the sale of iron and steel products. Products within this segment include sheet and tin plate bars, wire rods, forgings, beams, hot-rolled and cold-rolled strips, hot-rolled sheets, strappings and reinforcement mesh, pipes, tubing and concrete reinforcing bars. Together, these products are expected to generate at least 51.2% of revenue in 2015 and are expected to remain the main revenue-generating segment going forward. On the other hand the increasing growth rate of construction, automobiles, heavy machinery, and equipment is expected to drive consumption of metals used in these industries [3].

The metal industry is highly fragmented. Some of the major players in this industry are Arcelormittal, ThyssenKrupp, Rio Tinto, and BHP Billiton. A combination of factors such as growth in related industries and governmental regulations, cyclical fluctuations in metal prices, general economic conditions, and end-use markets are witnessed to impact the industry dynamics significantly. Moreover government regulations, rising cost of input materials, increasing operational efficiency in order to reduce operating costs, and improving the quality of output are some of the challenges being faced by the industry.

Government and the top management of the metallurgical companies expect benchmarking comparison of the efficiency and productivity of metallurgical units (companies, sectors) and they are interested in ranking metallurgical units from the best to the worst [4,5]. Whereas productivity evaluation approach considers actual infrastructure outputs, efficiency evaluation approach takes into account the maximum potential output which can be produced with the available inputs.

Full efficiency is attained by any industry sector if and only if none of its inputs or outputs can be improved without worsening some of its other inputs or outputs [6]. Many researchers have used various approaches to evaluate metal industry efficiency. There are numerous studies with Data Envelopment Analysis (DEA), for example, Lenort et al (2014) applied a DEA model to measure the efficiency of sectors manufacturing base metal in 25 European countries [7]. Similarly, Wysokinski et al (2014) compared the efficiency of mining and quarrying sector in 22 European countries [8]. Morfeld and Silveira (2014) used a DEA to investigate the energy efficiency of European iron and steel production from 2000 to 2010 [9]. Ma et al (2002) used DEA to evaluate the efficiency of China's iron and steel industry [10].

Productivity growth is considered necessary to produce higher quality goods in a more efficient manner, which results in lower costs to consumers, and also to raise per capita incomes over time [11]. In the industry, productivity traditionally has been considered important to the development process, allowing countries to produce more products at lower cost and release resources to other sectors [12, 13]. There are two partial productivity measures. First is labor productivity, the other is capital productivity. Moreover, the Malmquist Index is a bilateral index that can be used to compare the productivity of two economies, sectors or companies. In this paper, Malmquist Index approach was used to examine metal industry efficiency and productivity. In contrast to conventional production function or other index approaches, the Malmquist approach can distinguish between two sources of productivity growth: changes in technical efficiency and technical change [14]. When applied to panel data, this approach can also identify the innovator sectors over time. The Malmquist approach does not require the assumption of efficient production, but instead identifies the 'best-practice' countries or sectors in every period, which gives an efficient production frontier, and measures each country's or sector's output relative to the frontier. The purpose of this article is to determine changes in the productivity of the metal sector in US. The study aims to verify the following hypotheses:

H1: Changes in the technology were the main factor for improvements in the productivity of metal industry in US in 2006-2014.

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 [15] has further been studied and developed in Färe et al. [16; 17]. Färe et al. [16] constructed the DEA-based MPI as the geometric mean of the two Malmquist productivity indices of Caves et al. [18] - one measures the change in technical efficiency and the other measures the shift in the frontier technology. Färe et al. [17] developed it into the output-based Malmquist productivity change index. The input-oriented Malmquist productivity index of a DMU can be expressed as

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

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:

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

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. [17] 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).

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

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) [15].

3. RESULTS

The studies undertaken cover the US metal manufacturing sectors in years 2006-2014. The study was based on source data collected in the IBISWorld Industry Report regarding the following metal manufacturing sectors in US:

- metal pipe and tube manufacturing,
- metal stamping and forging,
- metal can and container manufacturing,
- metal plating and treating,
- metal tank manufacturing,
- metalworking machinery manufacturing.

In order to determine factors for changes in total productivity of US metal industry, the Malmquist Productivity Index was used. The calculated model uses the following variables:

- effect y_1 - revenue ($ m),
- effect y_2 - industry value added ($ m),
- input x_1 - number of people employed in metal industry (people).

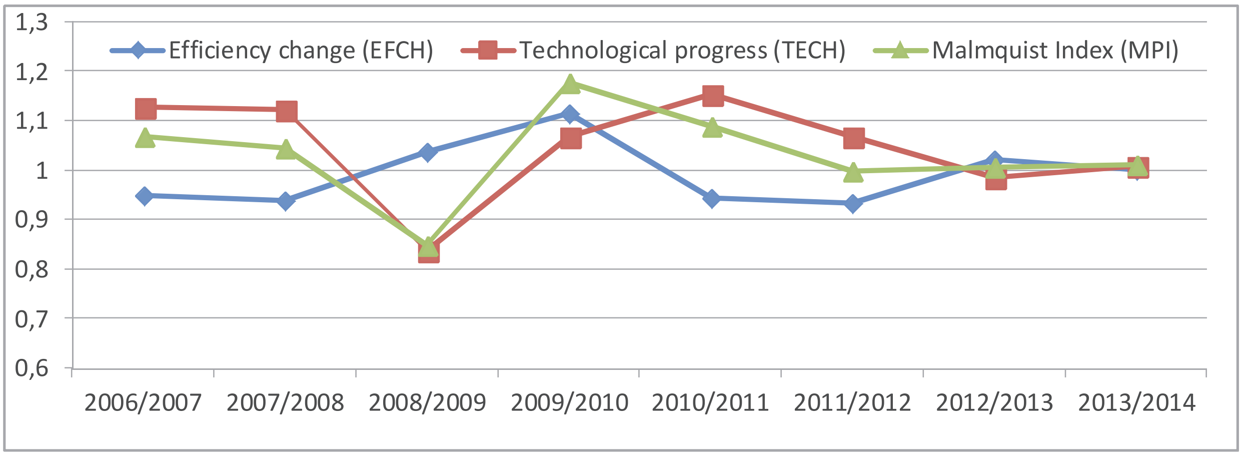

Fig. 2 Malmquist Productivity Index, changes in technical efficiency, changes in production technology calculated for metal industry in US

Source: Own calculations

The average annual growth of the Malmquist Productivity Index for US metal industry amounted to 3.2% (**Fig. 2**) in the period covered by the study. The most significant increase in metal productivity was recorded between 2009/2010. The Malmquist Index for the period was 1.18. The increase of the Malmquist Index was influenced primarily by changes in the technology employed. The average growth of the technological change index (TECH) was 4.7% for this period. In turn, the average change of the technical efficiency index (EFCH) was about 1% for the studied period.

In the period from 2006 to 2009 and 2009 to 2011 a visible decline in metal industry productivity in US has been observed and only in the (2009/2010) period did the Malmquist index increase to the level of 1.18 (**Fig. 2**). It can be concluded that a decrease in metal industry productivity was mainly influenced by adverse changes in technical efficiency. The index for these changes (EFCH) from 2009/2010 to 2011/2012 fell from 1.11 to 0.93, indicating a decrease in the technical efficiency of a metal industry over this period.

When analysing the average level of the Malmquist Index (MPI) in individual sectors one should consider that respectively, 5 out of the 6 sectors improved overall productivity over the studied period. The highest average annual increase in productivity was recorded in the following sectors: metal pipe and tube manufacturing (9%), metal plating and treating (3.4%) and metal stamping and forging (2.8%), with the lowest in metal tank manufacturing (**Fig. 3**).

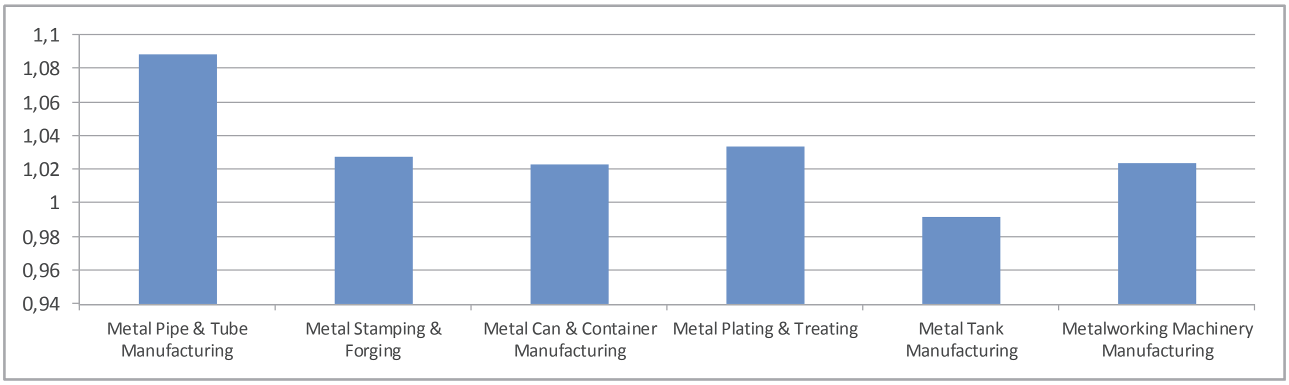

Fig. 3 Average annual Malmquist Productivity Index (MPI) calculated for sectors

Source: Own calculations

The highest average indices of changes in technical efficiency (EFCH) were recorded in metal pipe and tube manufacturing (1.04) and metal can and container manufacturing (1.01). In turn, the lowest (less than 1) annual average indices of changes in efficiency were observed in metal stamping and forging, metal plating and treating, metal tank manufacturing and metalworking machinery manufacturing (**Fig. 4**).

The largest average annual increases in the index of technological change (TECH) were recorded in metal can and container manufacturing (5.1%), other sectors recorded a similar index of technological change for example metalworking machinery manufacturing (4.9%), metal plating and treating (4.8%) and metal tank manufacturing (4.8%) (**Fig. 5**).

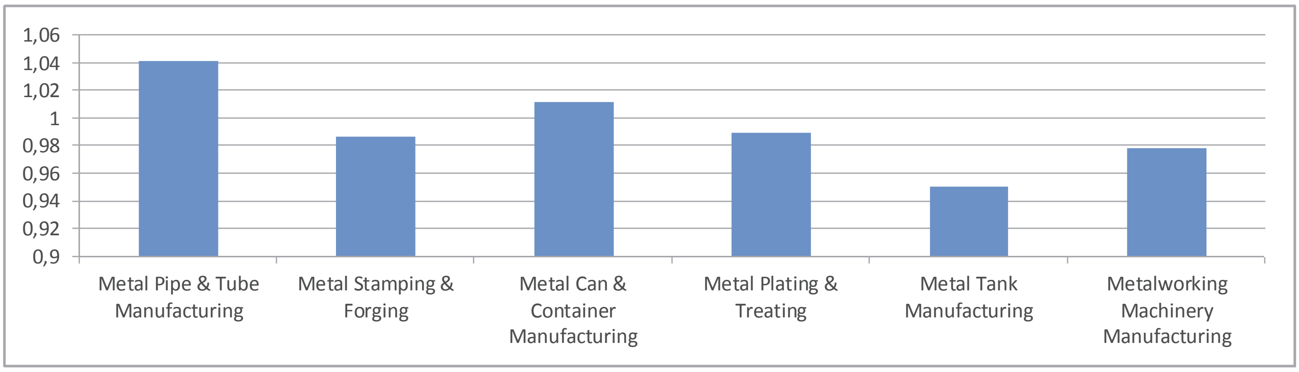

Fig. 4 Changes in technical efficiency (EFCH) for sectors

Source: Own calculations

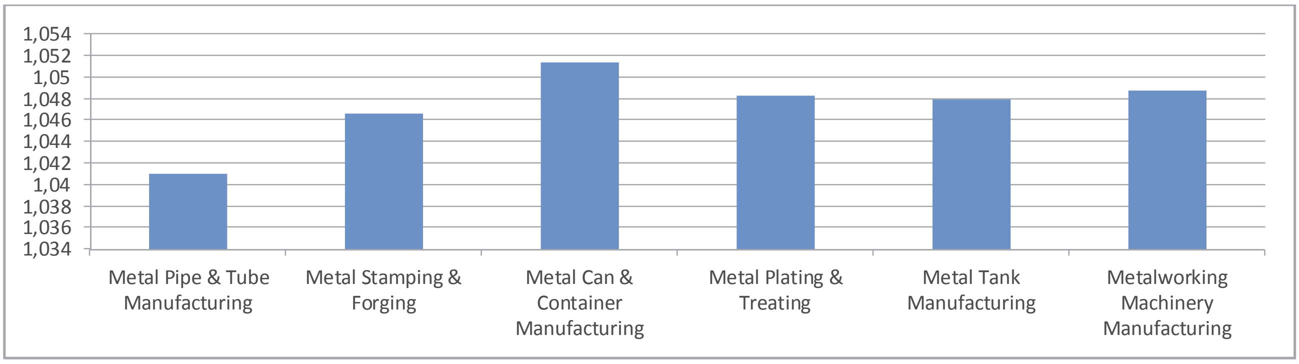

Fig. 5 Changes in production technology (TECH) for sectors

Source: Own calculations

4. CONCLUSIONS

In the article an analysis of the changes in the productivity of US metal industry in the 2006-2014 period was performed using the Malmquist Productivity Index. The results of the study have made it possible to indicate the general trend in the change of productivity in metal industry at the national level, as well as for individual sectors. The results of the analysis indicate that in 2006-2014 there was a relative increase in metal industry productivity (annual average by 3.2%). In 5 out of the 6 US metal sectors the average MPI index for 2006-2014 period was higher than one, which indicates an increase in sectors productivity. However, between individual periods both increases and decreases in productivity were observed. The highest annual average MPI indices were seen in: metal pipe and tube manufacturing, metal plating and treating.

A decomposition of calculated Malmquist indices has made it possible to identify what factors determined the change in metal industry productivity in US. It was found that technological progress was the main factor influencing the change in productivity of US metal industry in 2006-2014 - the conducted studies have therefore made it possible to accept hypothesis H1.

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