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MATHEMATICAL MODELING OF STRUCTURAL CHANGESIN THE INDUSTRIALSECTOR

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ABSTRACT

The role of industry in general and mainly processing industry in maintaining economic growth is placed under the thorough point of view in this paper. Brief review of concerned literature is performed as well. Trigonometric function has been applied in measuring the structural changes in industrial sector. Practical unit of the paper deals with structural changes estimating of the structure of industry sector of Uzbekistan. Econometric analysis of industry output influence on gross domestic product has been conducted and final conclusions have been worked out in the paper.

INTRODUCTION

The industry and its structural changes obtain significant importance in maintaining the sustainable economic growth. The experience of developing and newly industrial states shows that the economic achievements in those countries are at a great extent explained with the deep structural changes in the industry, especially in the processing industry. In general, a lot of researches (Lall, 2000; Szirmai and Verspagen, 2011; McMillan and Rodrik, 2011; Lavopa and Szirmai, 2012; Szirmai, Naudé and Alcorta, 2013) determine processing industry as the main driving force of the economic growth. Researches having examined the issue such kind of relationship in occurrence of the higher labor productivity in processing industry and as a result the stable growth of output has been defined.

The authors Lavopa and Szirmai (2012) consider processing industry as the mean of solving effectively such problems as providing required market equilibrium, improving competitiveness of economy, localization of production, employment and rising population income. Especially, processing industry has the specific importance in creating job places. Asexperts mention, creating one workplace in processing industry results in creating two or three workplaces in other sectors. However, complicated global economic processes taking place in the world economy for the last years have been causing serious structural changes in the countries' industry sector. This, in turn, aroused the necessity of investigating the case of sustainable industry development and structural changes of its components. This paper studies the industrial sector development and the structural changes in industry of Uzbekistan, as the country which provides high growth rate of GDP by means of implementing wide structural changes in economy, particularly in industry in the last years.

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Literature review

The notion "structure" refers to the core meaning of the structural change. In main sources the "structure" (from Latin "*structura"* - structure, system, location, order) is defined as stable interrelations between elements of the system and the internal form of the system and its composition. Main issues of the studies that are available have been under point of view of the most researchers, including Nobel prize-winners Leontief (1953), Kuznets (1966) and Solow (1964) as well. In particular, Solow (1964) empirically investigated the impact of changes in share of production factors in the industrial structure on economic growth rate. Similar researches (Pasinetti, 1981; Targetti, 2005; Guo, 2007; Lin and Lu, 2014; Libanio and Moro, 2015) have been deeply conducted where the quantity analysis of impact of processing industry on economic growth carried out in case of several countries (Latin America, China). Kaldor's scientific researches on the issue have been found significantly attractive of all studies and most of above mentioned works are based upon his scientific conclusions. In his researches Kaldor (1957) argued the reasons of high labor productivity exactly in the processing industry and its impact on the economic growth.

The typical feature of the most considered researches is that these studies have directly determined the impact of structural changes, especially of processing industry and its structural changes on the economic growth. However, the issues of measuring the structural changes in industry are not considered as a separate research object. The researches in some scientific sources (Moore, 1978; Vikström, 2001; Dietrich, 2012; Estola, 2011; Bonino and Willebald, 2013; Cortuk and Singh, 2013) serve as fundamental for the aim set. In particular, in his researches Moore (1978) investigated the structural changes in Yugoslavian industry as well as Vikström (2001) made the same analysis of structural changes in Sweden industry and economy. Our research is different from the researches above, and studies the structural changes in the general industry and sets marginal conditions to the index of structural changes.

Measurng structural changes

For measuring structural changes we use "cosine-coefficient" method applied in the researches of Moore (1978) and Vikström (2001). This method is based on calculation of angle cosine between the vectors. The method referred is interpreted in the case of the following two vectors.

For instance, $A = (s_{1,A}, s_{2,A})$ and $B = (s_{1,B}, s_{2,B})$ integral vectors are given. In this case cosine between angles is equal to following:

$$\cos(\theta) = \frac{\langle A, B\rangle}{\|A\|.\|B\|}, \qquad \text{where } 0 \le \theta \le \pi \qquad \text{.....................(1)}$$

If to insert to (1) appropriate coordinates of structural vectors in more detail, we'll receive the following formula:

$$\cos(\theta) = \frac{\langle A, B\rangle}{\|A\|.\|B\|} = \frac{\langle (s_{1,A}, s_{2,A}), (s_{1,B}, s_{2,B})\rangle}{\|(s_{1,A}, s_{2,A})\|.\|(s_{1,B}, s_{2,B})\|} = \frac{s_{1,A}\cdot s_{1,B} + s_{2,A}\cdot s_{2,B}}{\sqrt{(s_{1,A})^2 + (s_{2,A})^2}\cdot\sqrt{(s_{1,B})^2 + (s_{2,B})^2}} \qquad \text{......................(2)}$$

Now, we'll examine the issue of calculating angle cosine between vectors in *n*-dimensional space. Let's assume, in time interval $(t_1;t_2)$ a vector, set structure of which consists of $X^{t_1} = (x_1^{t_1}, x_2^{t_1}, \dots, x_n^{t_1})$ coordinates, changes after certain period to a vector set structure of which consists of $X^{t_2} = (x_1^{t_2}, x_2^{t_2}, \dots, x_n^{t_2})$ coordinates. In this case, a cosine of turning angle between vectors equals to the following expression:

$$\cos(\alpha) = \frac{(X^{t_1}, X^{t_2})}{|X^{t_1}|\cdot|X^{t_2}|} = \frac{\sum_{i=1}^{n} X_i^{t_1}\cdot X_i^{t_2}}{\sqrt{\sum_{i=1}^{n}(X_i^{t_1})^2}\cdot\sqrt{\sum_{i=1}^{n}(X_i^{t_2})^2}} = \frac{x_1^{t_1}x_1^{t_2} + x_2^{t_1}x_2^{t_2}\dots + x_n^{t_1}x_n^{t_2}}{((x_1^{t_1})^2 + (x_2^{t_1})^2\dots + (x_n^{t_1})^2)^{\frac{1}{2}}\cdot((x_1^{t_2})^2 + (x_2^{t_2})^2\dots + (x_n^{t_2})^2)^{\frac{1}{2}}} \qquad \text{.....................(3)}$$

This expression represents the strength of structural changes. Here, $\cos(\alpha)$ is a cosine of turning angle of structural vector, and $(X_1^{t_1}, X_2^{t_2})$ is a scalar multiplication of $X_1^{t_1}$ and $X_2^{t_2}$ vectors, $i = \overline{1,n}$.

Here, it satisfies the conditions where $\sum_{i=1}^{n} X_i^{t_1} = \sum_{i=1}^{n} X_i^{t_2} = 1$ and $0 \le X_i^{t_1}(X_i^{t_2}) \le 1$.

And also a cosine is in the range of $0 \le \cos(\alpha) \le 1$, and its value as much closer to 1, as the level of structural changes is high, and vice versa.

Dynamics of structural changes in industrial sector in Uzbekistan: empirical results

The average annual growth rate of the industrial production of Uzbekistan and the index of structural changes are shown in Table 1. According to it, the average annual growth rate of industrial production has been in high level (10.6%) during 2006-2010. For several years serious changes have occurred in the structure of industrial sector. Notably, in 2014 the industries as mechanical engineering and metal processing sector (19.2%), food industry (15.1%) and light industry (14.1%) were dominants.

Table 1. Growth rates of industry and index of structural changes in the Uzbekistan

Period	Average annual growth rate of industrial production (%)	Index of structural changes (coefficient)
1996-2000	4.4	0.97
2001-2005	7.7	0.95
2006-2010	10.6	0.96
2011-2014	8.1	0.97

Source: Author's calculations based on the data of the State Statistical Committee of Uzbekistan

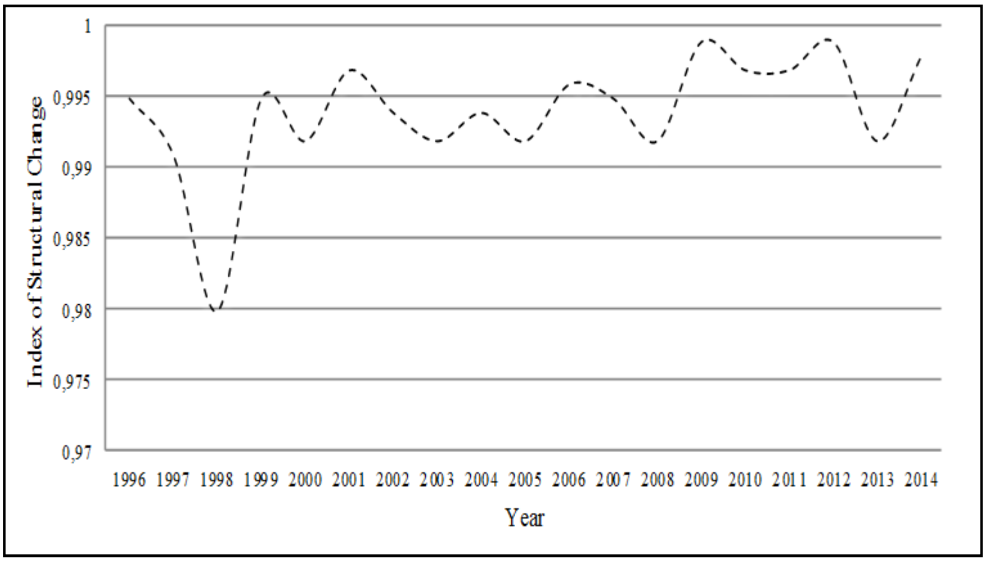
It should be emphasized that changing of the share of separate sectors in the structure of industry cannot give a clear conclusion about the whole structural changes in the industry. Therefore, the dynamics of generalized index of structural changes in industry is given below. The index of structural changes calculated by formula (3) has revealed the highest values almost for all years (see Figure 1).

In accordance with the results obtained, the index of structural changes in industry made up 0.994 in average during 1996-2014.

Factors of structural changes in industry and economic growth

The positive changes in the country's structure of industry and sustainable growth rate of production are explained with the following main factors:

- The state programs approved on sustainable development of industry;
- Macroeconomic sustainability and favorable investment environment of the country;
- Free economic and special economic zones created in the regions of the country;
- Commissioning of high-technology and modern industrial objects and production capacities;
- Further enlargement of the scope of production localization;
- Financial support of local production enterprises.

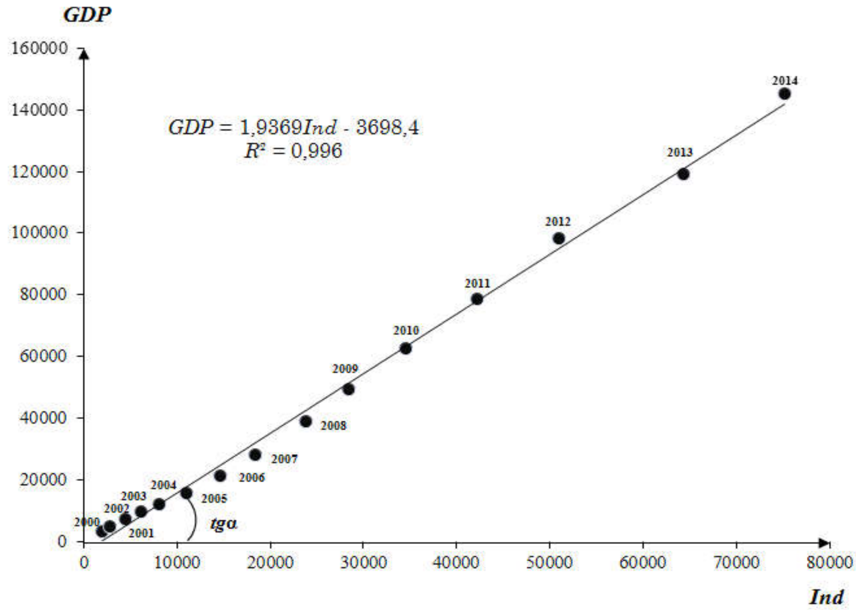


Source: Author's calculations.

Figure 1. Dynamics of structural changes in industrial sector (for 1996-2014)

As analyses show that through the generalized index of structural changes in industrial sector expresses the outcome of changes in the structure, however, it does not serve for making firm conclusion on development of industry. Particularly, the correlation coefficient between the average annual growth rate of industrial production and the index of structural changes in the sector is 0.34, consequently, the interrelation between these two parameters is very low. However, there is a positive correlation between industrial production and GDP. According to it, the growth of industrial production results in rising of GDP volume (Figure 2). The $GDP = 1.9369 Ind - 3698.4$ function represents the regression equation gained by econometrical analyses, and here, *GDP* and *Ind* refer, respectively, to the volume of country's gross domestic and industrial products during 2000-2014.

As shown in the graph, the regression coefficient is the angle tangent *tgα* (*tgα*=Δ*GDP*/Δ*Ind*), according to which the growth of industrial production to 1 unit results in the growth of GDP to 1.9369 point or approximately to 2 points.



Source: Author's calculations.

Figure 2. Correlation between industrial production and GDP (for 2000-2014 years, R^2 - determination coefficient)

The determination coefficient is equal to 0.996 which indicates that 99.6% of GDP total changeability is equal to the share of industrial production in regression equation.

Conclusions

The research and results of analysis show that the country's industry considerably affects the *GDP* dynamics. However, the index of structural changes in the industrial sector does not serve for making firm conclusion on development of industry. As it only quantitatively generalizes the level of positive or negative changes occurred in the structure of industry. Therefore, there is no exact correlation between the presented index and production.

Nevertheless, in the structure of production the absolute changes such as transfer of low-technology production to medium-technology production, transfer of middle-technology production to high-technology production, and shifting of sectors with low labor productivity towards the sectors with high labor productivity directly affects the growth of production. In addition, as all absolute changes in the structure are expressed in the volume of industrial production, there is a strong correlation (correlation coefficient is 0.998) between this index and economic growth.

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