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# Regression and correlation analysis of labour and resource productivity indicators compared within the V4 countries

***Abstract:*** *The paper is focused on the evaluation of labour and resource productivity compared within the Visegrad countries in the time period 2010 – 2015. The aim of the paper is to identify certain relations and connections between the indicators of labour and material resource productivity and compare the V4 countries from the perspective of these indices. The authors use the methods of the correlation and regression analysis and development trends.*
***Keywords:*** *correlation analysis, labour productivity, resource productivity, development trends, comparative analysis, V4 countries*

## Introduction

The concept of the so-called fourth industrial revolution, or Industry 4.0, was introduced at the trade fair in Hannover in 2013. In terms of this concept, it is assumed that the use of the methods and tools of Industry 4.0 will not only result in significant savings in time and money, but also the implementation of Industry 4.0 technologies will enable us to use material and human resources more effectively and increase their productivity.

The productivity indicator is one of the most important indicators of economic performance. It is thus natural that the expected intensive growth of productivity of all production factors has caught the increasing attention of the scientific economic public. Both scientists and laymen have discussed positive as well as negative impacts of this growth mainly on the employment rate, or changes in the structure of human resources.

Apart from this, problems of the labour productivity and material resource productivity development in relation to economic growth as a basis for the follow-up increase in real wages and living standard of the population have become the focal point of our attention.

Focusing entirely on the basic influences of the development of the fourth industrial revolution on economic growth (and social development) of the society exceeds the limitations of this paper. That is why the paper's authors focus only on the identification of possible relationships between the development of labour

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productivity and material resource productivity. The analysis focuses only on the Visegrad countries with regard to the afore- mentioned paper limitations.

## Objectives, indicators and methods

The aim of the paper is to identify certain relations and connections between the indicators of labour and material resource productivity and compare the V4 countries from the perspective of these indices.

The indicators of the resource productivity were used for the analysis. Resource productivity is, according to Eurostat[2], GDP divided by Domestic Material Consumption (DMC). DMC is defined as the total amount of material directly consumed within a certain economic system. It is a total amount of raw material extracted on a domestic territory of a particular economic system within a year plus all physical imports minus all physical exports. It should be noted that the term "consumption" as it is used in the case of DMC denotes the real consumption, not the final consumption. DMC does not include countervailing hidden flows in relation to the import and export of raw materials and products. For the calculation of resource productivity, Eurostat uses GDP in EUR in chain-linked volumes (given the reference year 2010 and the exchange rates of 2010) or in Purchasing Power Standard (PPS). In our research, we used the indicator in EUR per kilogram to compare the changes in each country at the time.

Resource productivity measures how efficiently natural resources are used by the economy and indicates whether economic growth is compatible with a more efficient use of the natural resources from the environment. Since 2008, resource productivity progressed in the EU both by increasing economic activity, as measured by GDP, and by reducing the extraction of materials, as measured by domestic material consumption (DMC). In the previous period between 2000 and 2008, GDP and domestic material consumption grew in parallel in the EU, leading to relatively constant resource productivity[3].

**Labour productivity is the second important and monitored indicator**

Each business entity operating effectively is interested in increasing labour productivity, since labour productivity is one of the main indicators of company performance. This issue has been often mentioned in discussions on the competitiveness of both local and foreign companies in the extended European market. In order to increase labour productivity, it is necessary to measure and monitor this indicator. Labour productivity is expressed as GDP per person employed.

Basically, it is the productivity of the national economy and it is designed as the index in relation to the EU 28 average. If this index is higher than 100 for a particular country, it means that GDP per employed person in this country is higher than the EU average and vice versa. The basic data is presented in the Purchasing Power Standard (PPS) – a common currency which blurs the differences in price levels among countries, allowing the comparison of GDP among the particular

[2] http://apl.czso.cz/pll/eutab/html.h?ptabkod=tsdpc100 Více informací najdete zde: http://ec.europa.eu/eurostat/statistics-explained/index.php/Material_flow_accounts_and_resource_productivity.

[3] http://ec.europa.eu/eurostat/documents/2995521/7546702/8-07072016-AP-EN.pdf/00e86912-73a0-4dc7-acaa-57c3b8db5e93.

countries. On this occasion, we do not distinguish whether the employed person is employed on a full time or part time basis.

The productivity growth is demonstrated by a decreased amount of labour expended on producing one item of production or by an increased amount of produced production using the same amount of expended labour. The savings in labour and labour costs, which appear when the production increases, depend on many factors. These factors mainly include:

- Amount and quality of capital investment in labour (the availability and performance of cooperative production factors, technological production changes, and modern technologies)
- Quality of workforce (education, qualifications, flexibility, and motivation)
- Effectiveness of using economic resources and their mutual combinations (the division of labour and specialization)
- Overall economic conditions (business cycle phases, political and social factors)
- Quality of natural resources (the availability of mineral raw materials, technological development, and import)
- Institutional and legislative framework of the economy (the protection of private rights, the enforceability of law, corruption, etc.)

It is obvious that both selected indicators are closely related, as both of them enter production at the same time. It would not be possible to reach any production level without the interdependence and cooperation of natural, capital and human resources. An ideal combination of these factors is needed to increase production and its effectiveness. The scientific discussion is primarily aimed at the measurement and size assessment of the mutual dependence and degree of cooperation.

From the theoretical-methodological point of view, the paper is based on the positivist economics and the general scientific methods of analysis, comparison, deduction, and synthesis are used to examine individual issues. The method of regression and correlation analysis was used to find out the relationship between both monitored indicators. Statistical-mathematical methods were used for the determination of the results. For the analysis, data from the Czech Statistical Office and Eurostat of the four countries of the so-called Visegrad Four (V4), i.e. the Czech Republic, Poland, Slovakia, and Hungary, was used.

The issue of labour productivity is also addressed in the scientific works of e.g. Dornbusch, Fischer (1990), Mankiew (1999), Jílek et al. (2001) and others.

**The method of correlation and regression analysis**

Since correlation and regression analysis represents the basic research method and method for reaching the assumed goal in the paper, the authors consider it suitable to include at least a brief note on this method.

Generally, the correlation analysis is used to study mutual symmetric dependencies while the emphasis is put on the intensity of the mutual relationship.

The task of the regression and correlation analysis is to mathematically describe systematic circumstances which accompany statistical dependencies. Our aim is to discover such an “idealizing” mathematical function which will best express the nature of the dependence and the most faithfully depict the process of changes of conditioned averages of the dependent variable. This mathematical function (hypothetical in its nature) is called the regression function. The aim is to get the empirical (calculated) regression function as close to the hypothetical regression function as possible. Statistical dependencies connected to the process of dependence and its intensity will be examined in our paper. The description of the dependence process is usually carried out by describing the particular dependence using a certain "balancing" analytical function. Some common mathematical functions represent these regression functions. The graphic form was chosen as the basic method of selecting the regression function. The graphic form depicts the process of dependence in the scatter plot, in which each observation pair *x* and *y* represents one point of this diagram. According to the characteristic course of the scatter plot, we try to decide which type of the particular regression function (line, parable, logarithmic function, etc.) would be the most suitable for the description of the monitored dependence. In order to determine the parameters of the regression function, the so-called method of least squares was used; it minimizes the sum of the squares of deviations of empirical values of the dependent variable from the theoretical values.

The Pearson´s correlation coefficient is used for measuring the force of linear dependence of the monitored characteristics and was used in our paper as well[4].

- It measures the statistical dependence of linear data (it is parametric),
- It is significantly influenced by outliers,
- It is calculated by means of standard deviations of the two variables and their covariance (the degree of mutual connection between the variables) using the formula:

$$r = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x})^2 \sum_{i=1}^{n}(y_i - \overline{y})^2}}$$

In this formula, the numerator shows the covariance of variables X and Y and includes the standard deviation of variables X and Y (see more in Anderson, Sweeney, Williams, 2008).

## Czech Republic

The development of productivity indicators concerning the Czech Republic in the years 2010-2015 is shown in Table 1. In the case of resource productivity, the increasing trend in the development of values can be traced except the year 2011, and labour productivity has also shown the growing trend since 2012.

[4] HINDLS, Richard. *Statistika pro ekonomy*. Praha, 2007.

**Tab.1. Productivity indicators in the Czech Republic in the years 2010-2015**

| **Year / indicator** | **Resource productivity** GDP/DMC | **Labour productivity per person employed (EU 28 =100%)** |
|---|---|---|
| 2010 | 0.9318 | 77.000 |
| 2011 | 0.9009 | 77.400 |
| 2012 | 1.0047 | 76.200 |
| 2013 | 1.0157 | 76.700 |
| 2014 | 1.0123 | 79.300 |
| 2015 | 1.0260 | 79.900 |

Source: authors, on the basis of Eurostat data.

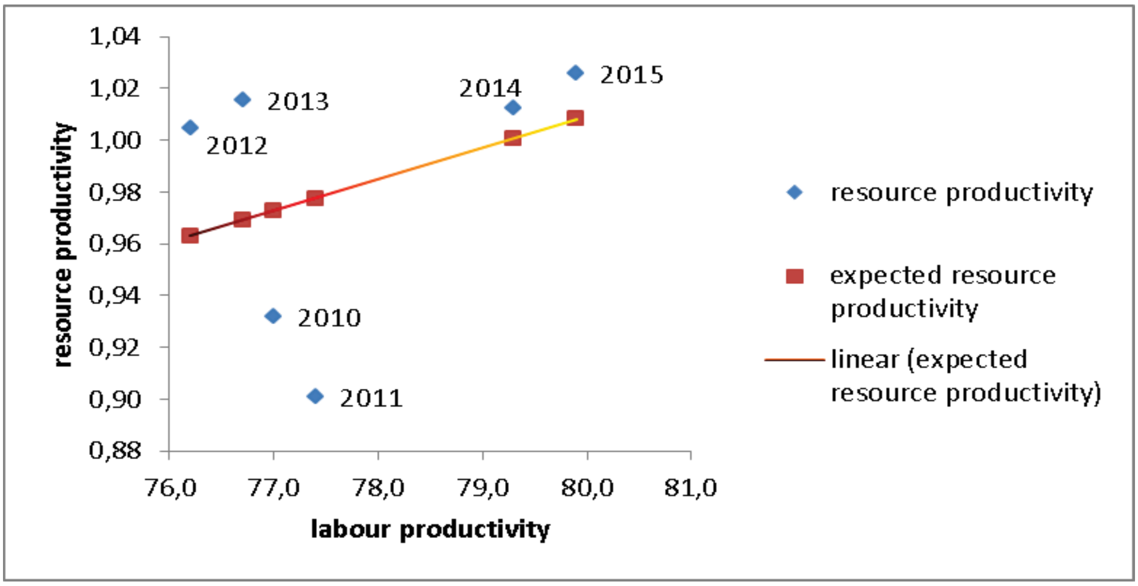


**Figure 1. The comparison of values of labour and resource productivity in the Czech Republic in the years 2010-2015**
Source: authors, on the basis of Eurostat data.

Figure 1 represents the dependence between both indicators and also the trend of expected resource productivity. The linear equation for the development trend of the indicator is:

$$y = 0.0122x + 0.0319$$

The Pearson´s correlation coefficient equals 0.350841 for the Czech Republic. This value corresponds to the moderate level of dependence. The reason is probably the significant deviations from the expected development, especially in the years 2010 and 2011, which could be mainly caused by an increased export of resources.

## Slovakia

In Slovakia, the situation was developing differently, as seen from Table 2. The development of both resource productivity and labour productivity has been fluctuant.

**Tab. 2 Productivity indicators of the Slovak Republic in the years 2010-2015**

| **Year / indicator** | **Resource productivity** GDP/DMC | **Labour productivity per person employed (EU 28 =100%)** |
|---|---|---|
| 2010 | 0.9376 | 83.600 |
| 2011 | 0.9325 | 81.600 |
| 2012 | 1.0923 | 82.500 |
| 2013 | 1.1597 | 83.800 |
| 2014 | 1.0748 | 84.100 |
| 2015 | 1.0382 | 83.300 |

Source: authors, on the basis of Eurostat data.

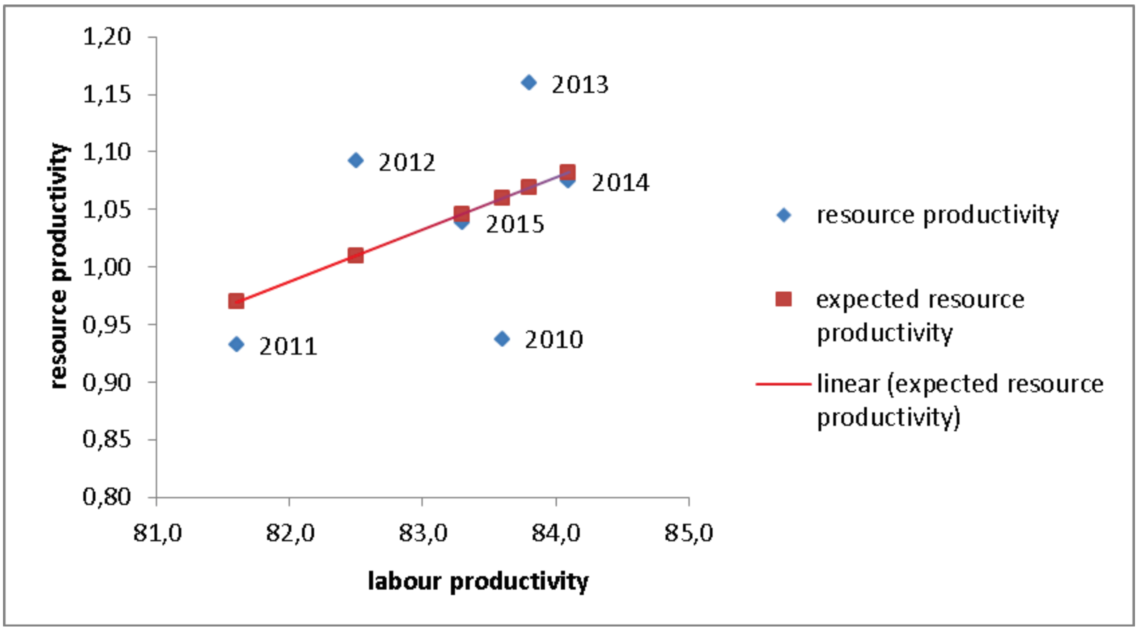


**Figure 2. The comparison of values of labour and resource productivity in Slovakia in the years 2010-2015**
Source: authors, on the basis of Eurostat data.

Even though the indicators have this unspecific character, a certain development trend can be found using the regression and correlation analysis. The linear equation for the development trend of the indicator is: $y = 0.0451x – 2.7077$.

The Pearson´s correlation coefficient equals 0.469418 which is close to the higher level of the correlation dependence of the monitored indicators.

## Poland

The value of the Pearson´s correlation coefficient for productivity indicators of Poland equals 0.417352 which represents a moderate to higher level of dependence. In comparison with other V4 states, the values are lower, which is caused by a higher proportion of exported material resources. Labour productivity per person employed has developed in an increasing manner, even though it often slightly fluctuates. The linear equation for the development trend of the indicator is: y = 0.0154x – 0.5534.

**Tab. 3. Productivity indicators of Poland in the years 2010-2015**

| Year / indicator | **Resource productivity** GDP/DMC | Labour productivity per person employed (EU 28 =100%) |
|---|---|---|
| 2010 | 0.5610 | 70.200 |
| 2011 | 0.4761 | 72.700 |
| 2012 | 0.5548 | 74.100 |
| 2013 | 0.5946 | 74.000 |
| 2014 | 0.6166 | 73.900 |
| 2015 | 0.6413 | 74.300 |

Source: authors, on the basis of Eurostat data.

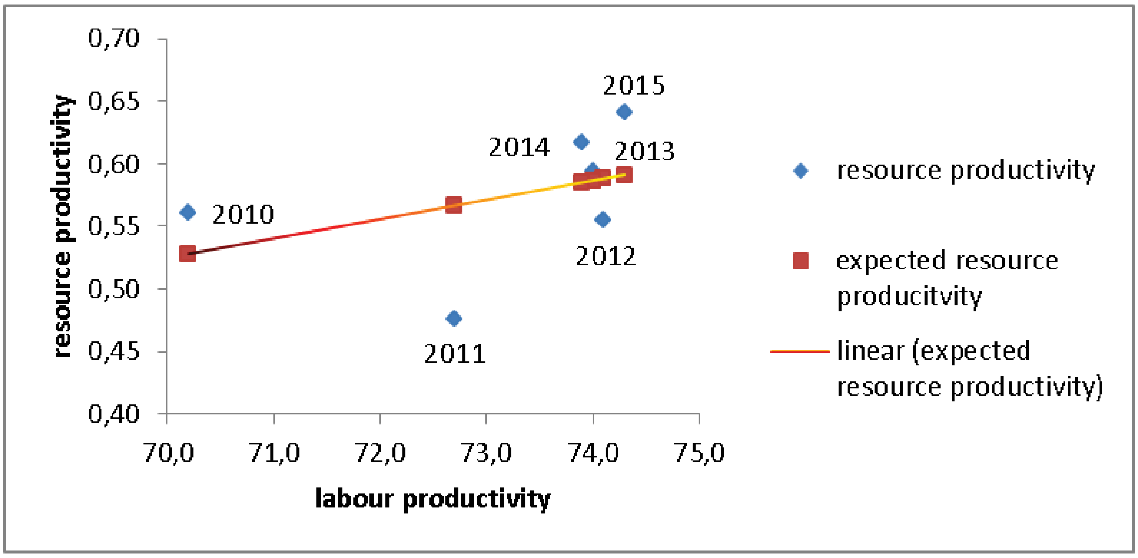


**Figure 3. Comparison of values of labour and resource productivity in Poland in the years 2010-2015**
Source: authors, on the basis of Eurostat data.

## Hungary

The values of the two selected indicators in the monitored years are presented in Table 4.

**Tab. 4 Productivity indicators of Hungary in the years 2010-2015**

| **Year / indicator** | **Resource productivity** GDP/DMC | **Labour productivity per person employed (EU 28 =100%)** |
|---|---|---|
| 2010 | 0.9820 | 72.700 |
| 2011 | 1.0070 | 73.800 |
| 2012 | 1.1388 | 72.500 |
| 2013 | 1.0115 | 72.900 |
| 2014 | 0.8288 | 71.000 |
| 2015 | 0.8836 | 70.300 |

Source: authors, on the basis of Eurostat data.

Graph 4 shows the values of resource productivity and labour productivity on the basis of the calculation of the Pearson´s correlation coefficient which reaches the high value of 0.678281, which represents the higher level of correlation dependence. The linear equation for the development trend of the indicator is: $y = 0.0567x – 3.118$.

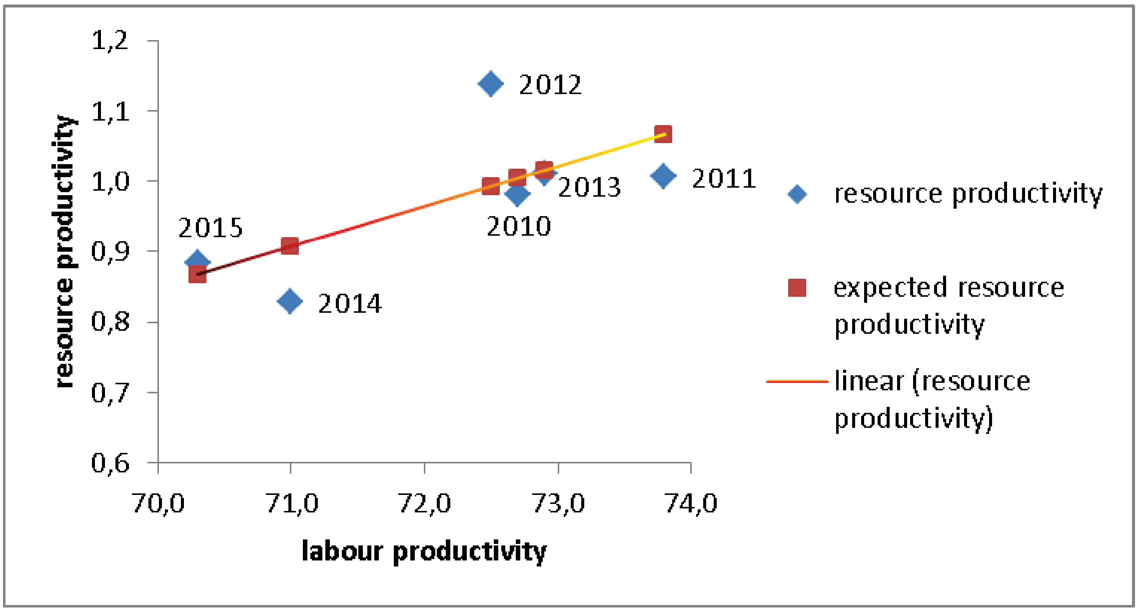


**Figure 4. Comparison of values of labour productivity and resource productivity in Hungary in the years 2010-2015**
Source: authors, on the basis of Eurostat data.

## Discussion and conclusion

To exemplify, graphs 5 and 6 are shown, in which the development of resource productivity and labour productivity in particular countries in the monitored period is apparent.

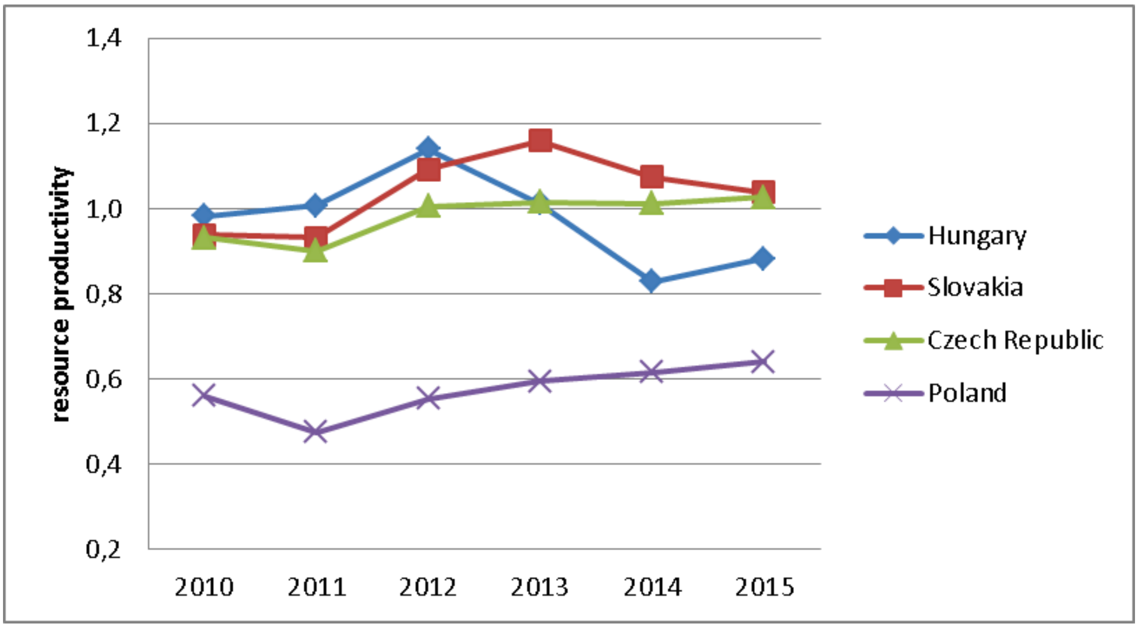


**Figure 5. Development trend of resource productivity in the V4 countries in the years 2010-2015**
Source: authors, on the basis of Eurostat data.

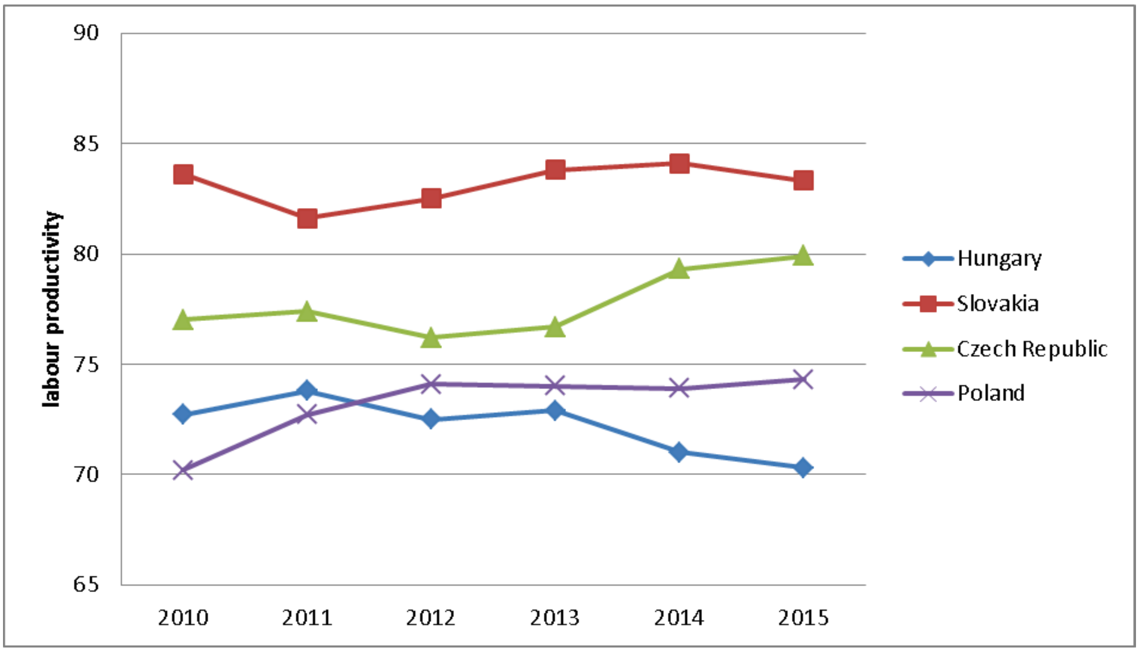


**Figure 6. Development trend of labour productivity in the V4 countries in the years 2010-2015**
Source: authors, on the basis of Eurostat data.

The calculated values of individual countries are mutually compared and shown in graphs 7 and 8. If we mutually compare the values of individual indicators, we will find out that in certain years the dependence has been proven.

Even a high value of the correlation coefficient does not necessarily mean causal dependence between variables. Especially with the choices of a small range, it is necessary to assess the obtained results carefully. In the case of linear independence of variables x and y, the correlation coefficient in the basic set will equal zero. The null hypothesis will be taken down the following way:

***$H_0$: r = 0.***

Against this presumption, a hypothesis of nonzero value r will be posed in the form

***$H_1$: r ≠ 0.***

The following variable can be used as the test criterion:

$$T = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

which can be proven having the division *t* with *n-2* level of freedom if selected from the two-dimensional normal division. If the calculated value of the test criterion falls within the critical field, the null hypothesis will be rejected and the existence of linear dependence at the chosen level of significance will be considered proven.

For the Czech Republic, the value of the test criterion equals $T = 1.499$. In quantile tables of Student´s division t, the critical value $t = 2.132$ is found at the 5% level of significance for 4 levels of freedom. Since 1.499<2.132, it means that the value of the test criterion falls within the acceptance field and the hypothesis $H_0$ cannot be rejected at the 5% level of significance. The existence of linear dependence between variables in the basic set is not considered proven. The same conclusions are drawn from testing the correlation coefficient for Slovakia since the value of the test criterion compared with the critical value equals: 2.127<2.132. The same conclusion is reached for Poland after the two values were compared: 0.9186<2.132. If the hypothesis on the correlation coefficient is tested for Hungary, the value of the test criterion $T = 3.692 > 2.132$ is calculated, the null hypothesis is rejected at the chosen level of significance 5%, and the existence of linear dependence can be considered proven in this case.

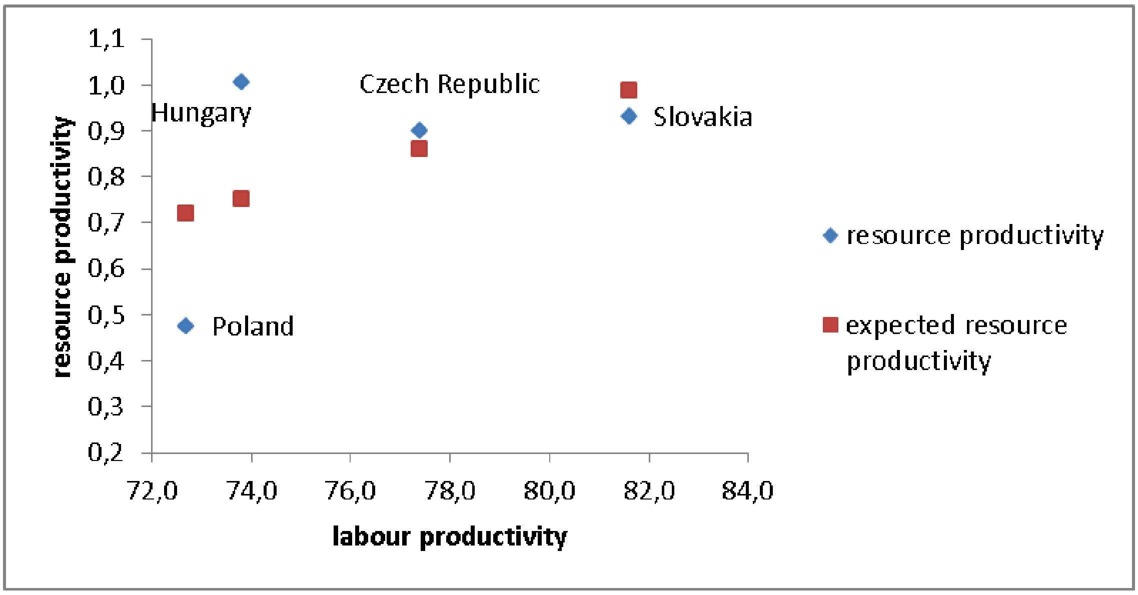


**Figure 7. Comparison of the Visegrad countries in 2011**
Source: authors, on the basis of Eurostat data.

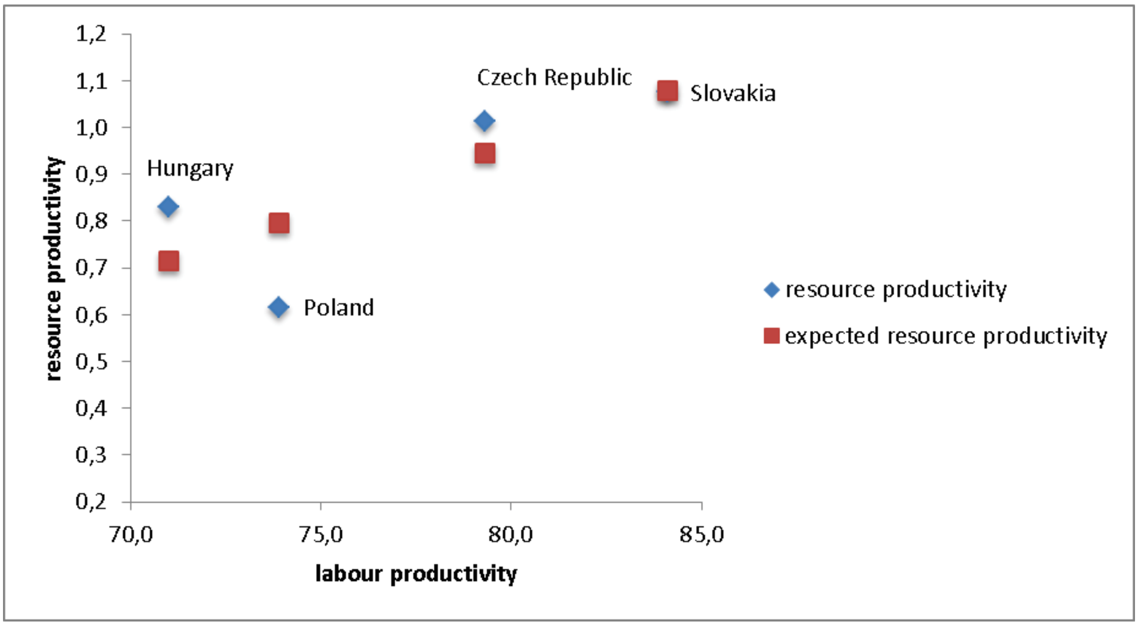


**Figure 8. Comparison of the Visegrad countries in 2014**
Source: authors, on the basis of Eurostat data.

Labour productivity per person employed and the productivity of material resources in relation to GDP were investigated by means of the correlation and regression analysis methods. By comparing the calculated indicators we can conclude that the highest dependence has been demonstrated in the case of Hungary and the lowest value of the Pearson´s correlation coefficient in the case of the Czech Republic. This comparison is recorded in the summarizing Table 5.

**Tab. 5 Values of the correlation coefficients in the monitored countries**

| The Visegrad country | Pearson´s coefficient value |
|---|---|
| Czech Republic | 0.350841 |
| Poland | 0.417352 |
| Slovak Republic | 0.469418 |
| Hungary | 0.678281 |

Source: authors.

The results of the correlation and regressive analysis can indicate and confirm that in some years:

1. GDP/DMC is lower, and therefore export exceeds import
2. Resource productivity lags behind the labour productivity.

The Czech Republic and Slovakia are probably better in using modern technologies and increase the value of labour productivity in such a way. In the case of Hungary, both indicators are more interdependent. Changes in the development of the monitored indicators can be caused by a variety of economic and non-economic indicators which, moreover, come across as simultaneous and random.

The amount of resources used by an economy plays a crucial role in the generation of environmental pressures, from the extraction of natural resources for production and consumption activities to materials released into the environment, e.g. disposal of waste and emissions to air and water. Moving towards a circular economy is at the heart of the resource efficiency agenda established under the Europe 2020 strategy for smart, sustainable and inclusive growth.[5]

Samuelson (2010) states that the decrease in productivity can be caused for example by:

- Increase in oil prices;
- Stricter regulations of esp. prices and wages;
- Regulation of the energy industry;
- Reductions in expenditure on research and development.

On the contrary, the growth of productivity is always associated with the use of modern information technologies and innovations in these technologies (software, hardware and telecommunications):

- Economies of scale;
- Technological change;
- Sharp rise in productivity in the area of IT;
- Capital deepening (increase in investment);

In any case, to increase productivity, the need for development and implementation of innovations, mainly in the fields mentioned above, transportation, logistics, etc., is urgent these days.

We can also mention the issue of unmeasured output, i.e. the productivity of software and telecommunication technologies. This productivity is rather under-

[5] http://ec.europa.eu/eurostat/documents/2995521/7546702/8-07072016-AP-EN.pdf/00e86912-73a0-4dc7-acaa-57c3b8db5e93.

estimated. A new or follow-up research could divert from material productivity and focus more in this direction.

From the perspective of the statistical processing of the obtained data, the extension of the investigation to other countries, e.g. within the EU, or to carry out the research over a longer period of time and thereby obtain a larger amount of data for further possible statistical conclusions can be proposed for the follow-up research.

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