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Research Article

Comparative Analysis of Industrial Development in Germany, Austria and Slovakia: The Problems and Perspectives

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Abstract: *In this study, three countries of the EU (Germany, Austria and Slovakia) were selected for the analysis of the development of industry. These countries were chosen due to the important role of industrial sectors in the formation of GDP and employment. In addition, Germany and Austria, and Austria and Slovakia have joint borders, which is important for the analysis of spatial effects and diffusion of the investments and technologies from the west to east, and migration of labor force in opposite directions. The main objectives of this study are: on the basis of the main indicators from Eurostat to characterize the role and long-term tendencies of the development of industry in the mentioned three countries; to define the regimes of industrial development using cluster analysis and to apply the integral index for the evaluation of the industrial development in these countries for the comparative analysis and projections. The main indicators of the development of the industry were analyzed in the long-term period, during 2000-2020 years, and the basic models for the time series were built; the projections for the main indicators are made for the next 5 years. To take into account the set of the main indicators of the industry in these countries and to provide a comparative analysis of the complex situation, the integral indices were calculated, and the features of the development of the industry were characterized.*

Keywords: *Cluster Analysis, Development, Econometric Models, Employment, Industry, Integral Index.*

I. INTRODUCTION

The industry represents approximately 25% of the world's GDP, and nearly 23% of worldwide employment is in the industrial sector. The data are varied across countries and macro-regions, but industry plays an important role in the contribution of total output in each country of the world. The industry is a major force in growth, and Europe, it employs some 32 million people, and another 30 million work in industries associated with it. The European economy focuses on the new challenges for industrial development and its long-term competitiveness.

In this study, three countries of the EU (Germany, Austria and Slovakia) were selected for the analysis of the development of the industry. These countries were chosen due to the important role of industrial sectors in the formation of GDP and employment. In addition, Germany and Austria, and Austria and Slovakia have joint borders, which is important for the analysis of spatial effects and diffusion of the investments and technologies from the west to east, and migration of labor force in opposite directions.

The main objectives of this study are: on the basis of the main indicators from Eurostat to characterize the role and long-term tendencies of the development of industry in the mentioned three countries; to reveal the features of the development of the industry in these countries using the calculation of growth rates and ratios for the main indicators; to define the regimes of the industrial development using cluster analysis and to apply the integral index for the evaluation of the industrial development in these countries for the comparative analysis and projections.

II. LITERATURE REVIEW

The problems of the modern development of the industry and new perspectives for the growth of the industrial potential in well-developed and emerging countries were considered in the numerous research, papers and reports since the second half of the XX century and over last few decades these topics are intensively discussed due to the rapid technological progress and crucial innovations in the production and society (Jewkes, 1951; Pollard,1973; Cameron, 1985; Lall, 1991; Regnerova et al, 2021; Chen et al, 2023). The industrialization experiences of developing nations differ significantly. The "newly industrializing countries" (NICs) of East Asia represent one extreme of the spectrum. These countries have had rapid and steady expansion in their manufacturing sectors and are now competing globally in a wide range of high-tech industrial goods. Their economies' structural transformation and income growth have been driven by industrial development (Lall, 1991; Homma, T, 2021; Chen et al., 2023).

The industry is currently going through a transitional stage as it advances from Industry 4.0 to the nascent field of Industry 5.0. Industry 4.0 is the intelligent flow of workpieces in a factory, machine by machine, with real-time machine-to-machine communication. Industry 4.0 transforms manufacturing in this environment by utilizing collaborative, adaptable systems to solve issues and arrive at the optimal choices. It is a positive step forward for the industrial scenario that focuses on developing intelligent processes, intelligent products, and intelligent procedures (Alcácer, Cruz-Machado, 2019). Industry 5.0 aims to improve upon the integration, automation, scalability, and real-time responsiveness ideas introduced by Industry 5.0 by promoting a new era of human-machine coexistence and cooperation (Banholzer, 2022). The crucial role has belonged to the technologies and well-educated and motivated human resources (Mouzakitis, 2010; Petrovski, 2011; Bardeau, 2017; Naqshbandi, Jasimuddin, 2018; Dubrovina et al., 2022). Technology is pervasive in today's environment and benefits every industrial sector segment that chooses to invest in it. Industrial technology is a tool of knowledge that is applied to the industrial sector to improve production processes and their efficiency. It includes ideas, instruments, equipment, and more. Among the new industrial technologies, it is necessary to identify significant market advancements, such as automation, robotization and artificial intelligence (Dauth et al., 2017; Seifert et al., 2018; Masood, Egger, 2019). Automation and robotization are important parts of the concept of Industry 4.0, where sophisticated or extremely intelligent machinery on the manufacturing line is implemented (Bortolini, 2017; Masood, Egger, 2019). Artificial Intelligence (AI) is the scientific powerful intellectual platform to develop machines with computational capacities similar to those of humans. AI includes the ability to collect, evaluate, comprehend, and link complicated data while always learning new things and adaptation of previous and new knowledge, data, facts, and ideas. All of these reasons concerning the revolutionary technologies require new capacities for the industry and its human resources.

As Ch. P. Bown mentioned (2023), the temporal industrial policy is distinct from that of the past. Unlike emerging nations, it is frequently aggressively sought by large, high-income industrial economies like the US, the EU, and Japan. Some of the linked WTO challenges are being driven by China's use of industrial policy, which is also inspiring these new users - at times, to defend their economies from China, at other times to use industrial policy themselves.

Taking the problem of increasing competitiveness in the modern industrial sector and the role of globalization, it is important to provide an analysis of the development of the industry in the selected countries of the EU and to reveal the features of tendencies of the main indicators in the industry on the example of these countries.

III. RESULTS AND DISCUSSION

This study is focused on the comparative analysis of the industrial development in three EU countries – Germany, Austria and Slovakia. The adjustment of the selection of these countries is based on the idea of comparing the tendencies in well-developed EU countries with the industrial framework created during a long-run period and the tendencies in the formation of new industrial potential in post-Soviet or emerging countries of EU, which became the new members of EU after 2005. As it is known, Germany and Austria are examples of old EU members, where industry plays an important role in the economics and technological progress. Slovakia is an example of of post-Soviet country, where the crucial changes in the character of the economy and political system explained the crisis in the 1990s. Nevertheless, the last two decades were successful for the economy in Slovakia, when the powerful largest international industrial companies began to invest in the development of industry in Slovakia and a few well-known giants and big companies from the automotive sector, machine building, electronics, IT -sector run their networks in Slovakia. Due to its attractive geographical location in the center of Europe, good infrastructure and special EU programs, Slovakia was an attractive place for foreign investments.

When conducting a comparative analysis of industrial development in Germany, Austria and Slovakia, it is important to take into account significant differences in the absolute values of socioeconomic indicators due to the scale of these countries and different levels of social and economic standards. Germany is one of the leading EU countries, with a territory of 357 592 sq. km. and the population in 2020 was 83 million 161 thousand people. Austria occupies an area of 83 879 sq. km, and the population in 2020 was more than 8 million 916 thousand people. Slovakia is a small country with an area of 49 034 sq. km, and the population in 2020 was 5 million 460.51 thousand people.

As is seen, the size of the territory of Germany is more than 4.2 times larger than the territory of Austria and 7.3 times larger than the territory of Slovakia. Austria has a territory 1.7 times larger than Slovakia. The population in Germany is 9.3 times larger than the population in Austria and more than 15 times larger than in Slovakia. In Austria, the population is 1.6 times higher than in Slovakia.

In 2020, GDP in Germany amounted to 3 403 730 million euros; in Austria, this figure was 380 888.5 million euros, and in Slovakia – 93 444.1 million euros. Thus, the level of GDP in Germany was more than 8.9 times higher than the GDP of Austria, and compared to Slovakia, the level of GDP in Germany was 36.4 times higher. Such significant differences are explained by the different scales of countries, as well as differences in price levels and purchasing power, differences in socioeconomic standards, levels of technological progress, etc.

For a comparative analysis of the level of socioeconomic development of countries, it is important to calculate GDP per capita. In 2020, the GDP per capita in Germany was 40 930 euros, in Austria – 42 720 euros, and in Slovakia - only 17 110 euros. Thus, in 2020, GDP per capita in Austria was 4% higher than in Germany. In 2020, GDP per capita in Germany was 2.4 times higher than in Slovakia, and GDP per capita in Austria was almost 2.5 times higher than in Slovakia.

In 2020, the number of people employed in the German economy was 59 248 751 people, of which 11 379 418 people were employed in various industrial branches. In Austria in the same year, the number of people employed in the economy was 6 709 180 people, of which 1 094 770 people worked in the industry. In Slovakia, the number of people employed in the economy totalled 3 771 291 people, while 882 626 people were employed in the industry.

Thus, the number of people employed in the whole German economy exceeded similar indicators in Austria and Slovakia by more than 8.8 and 15.7 times, respectively. In Austria, the number of people employed in the whole economy was 1.78 times higher than the same figure in Slovakia. As for the ratio of the number of people employed in industry, in Germany, this figure was 10.4 times higher than in Austria and 12.9 times higher than in Slovakia. In Austria, the indicator of employment in industry was 1.24 times higher than the same indicator in Slovakia.

At the same time, to conduct a comparative analysis of socioeconomic indicators of countries, it is necessary to take into account not only simple approaches but also more complex methods that allow one to study the relationships between various indicators, the features of their changes over time, comparison with reference values, etc.

Thus, for the detailed comparative analysis of the industrial development, the statistical methods, cluster analysis and evaluation of integral indices were used. In the first stage the selection of the main indicators was argued, description of their tendencies and graphical presentation were carried out. In the second stage, the grouping of the states in the industry to the clusters was made. In the third stage, the values of the integral indices were calculated, and the nonlinear dynamics were demonstrated. In the fourth stage the ARIMA were used for the modeling of the current tendencies of integral indices. In five stages, the calculation of the predicted integral indices of industrial development was made and possible scenarios were discussed.

In this research, such important indicators such as Gross Value Added (GVA) in the economy, total (million, euro); Employed persons from 15 till 64 in the economy, total (persons); Gross Fixed Capital Formation (GFCF) in the economy, total (million, euro); Compensation of employed in the economy, total (thousands); Gross Value Added (GVA) in the industry, total (million, euro); Employed persons from 15 till 64 in the industry, total (thousands); Gross Fixed Capital Formation (GFCF) in the industry, total (million, euro); Compensation of employed in the industry, total (thousands) were used. In addition, other indicators were calculated as the ratio of absolute magnitudes to the number of employed persons. Also, ratios for the main indicators in industry to the related indicators in the whole economy were estimated, and annual growth rates of indicators were determined.

The main indicators of the development of the industry were analyzed in the long-term period, during 2000-2020 years, and the basic models for the time series were built; the projections for the main indicators are made for the next 5 years. For preliminary study of data, it is reasonable to use descriptive statistics methods to calculate characteristics such as sample means, minimum and maximum values, standard deviations and coefficients of variation. Table 1 shows calculations of the indicated characteristics for the main industrial indicators for Germany, Austria and Slovakia.

Table 1: Descriptive statistics for some indicators for industry and its role in the economy in Germany, Austria and Slovakia

Indicator	Min	Max	Mean	Std.Dev.	Coef. variation	Max/Min
Germany						
Employed persons	11071338	12748471	11903426	396355,5	3,33	1,15
Compensation in Industry	326421	477719	378714,9	52431,36	13,84	1,46
Gross fixed capital formation	100208,5	175487	126267,9	22738,73	18,01	1,75
Gross value added	486433	781868	614384,1	101922,4	16,59	1,61
Austria						
Employed persons	1094770	1213860	1143362	33746,64	2,95	1,11
Compensation in Industry	25020	41643	31734,29	5490,43	17,3	1,66
Gross fixed capital formation	10646	22433	15139,86	3817,79	25,22	2,11
Gross value added	46109	76764	61002,24	9656,23	15,83	1,66

Slovakia						
Employed persons	882626	1043445	958936,5	41078,19	4,28	1,18
Compensation in Industry	2592,35	10891,75	6362,15	2635,42	41,42	4,2
Gross fixed capital formation	1906,99	6989,61	4971,68	1482,26	29,81	3,67
Gross value added	5457,04	22424,28	14466,98	5133,23	35,48	4,11

Source: *Own Calculation*

As can be seen from the results presented in Table 1, Germany is the leader in absolute indicators, which is explained by the rather large size of the country and the significant role of industry in the economy of this country. Thus, the absolute values for minimal, maximal and mean values of the indicators calculated for the number of employed in the industry in Germany during the period of 2000-2020 are more than 10 times higher than similar indicators in Austria and more than 12 times compared to Slovakia.

The value of the compensation (total wage fund and social contributions) for people employed in industry in Germany is more than 11 times than similar indicators in Austria and more than 40 times higher than in Slovakia. Moreover, in the initial period in 2000, the difference between these indicators in Germany and Slovakia was even higher and then gradually decreased. In 2000, in Austria, the indicator of compensation for employed in the industry was 9.5 times higher than a similar indicator in Slovakia, and then this difference decreased to 3-4 times. The fund of gross fixed capital formation in industry in Germany was more than 8-9 times higher than in Austria. Compared to Slovakia, this figure was 52 times higher in 2000, and then the difference decreased to 25 times. In 2000, in Austria, the fund of gross fixed capital formation in industry was more than 8 times higher than the same indicator in Slovakia. This difference in indicators amounted to 3-4 times. Gross value added in Germany is more than 10 times higher than in Austria and more than 30 times higher than in Slovakia. The gross value added indicator in Austria in the early 2000s was more than 8 times higher than in Slovakia, then this gap in 2020 narrowed to 3 - 4 times, which demonstrates the significant economic growth in Slovakia over the past 20 years and the trend of gradual alignment with EU countries comparable in territory and population.

At the same time, in order to conduct a comparative analysis between these countries without taking into account the influence of the country's scale, relative indicators should be calculated per capita or in terms of per employee. Also, to compare the dynamics of the development of countries, it is advisable to calculate growth rates of absolute or relative indicators and to study trends in changes in indicators over time.

To analyze the dynamics of changes in indicators over time and build trend models, it is necessary first to conduct a visual analysis of the graphs. The graphs presented below were constructed based on time series for basic and relative indicators calculated per employee. Figure 1 shows graphs of gross value added in industry per employee for Germany, Austria and Slovakia.

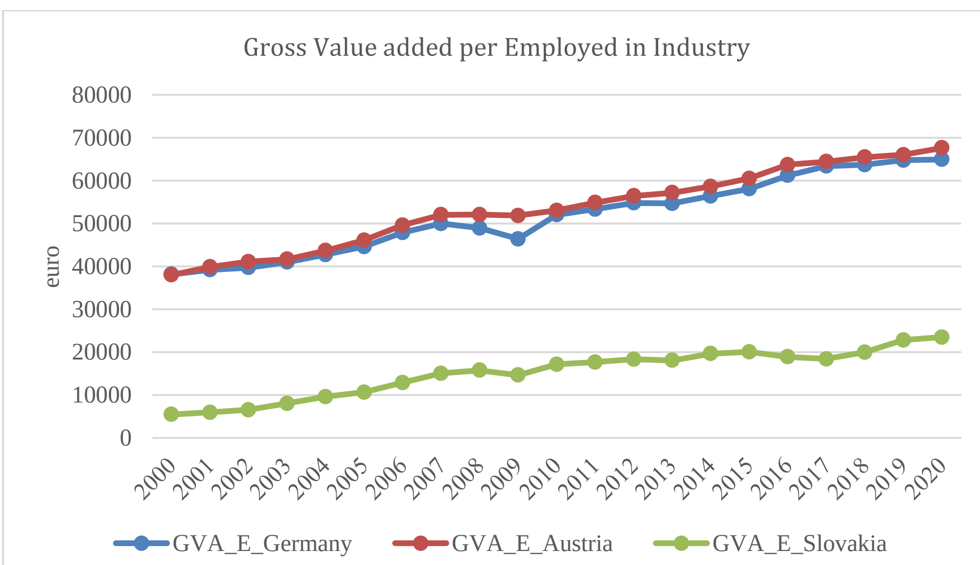
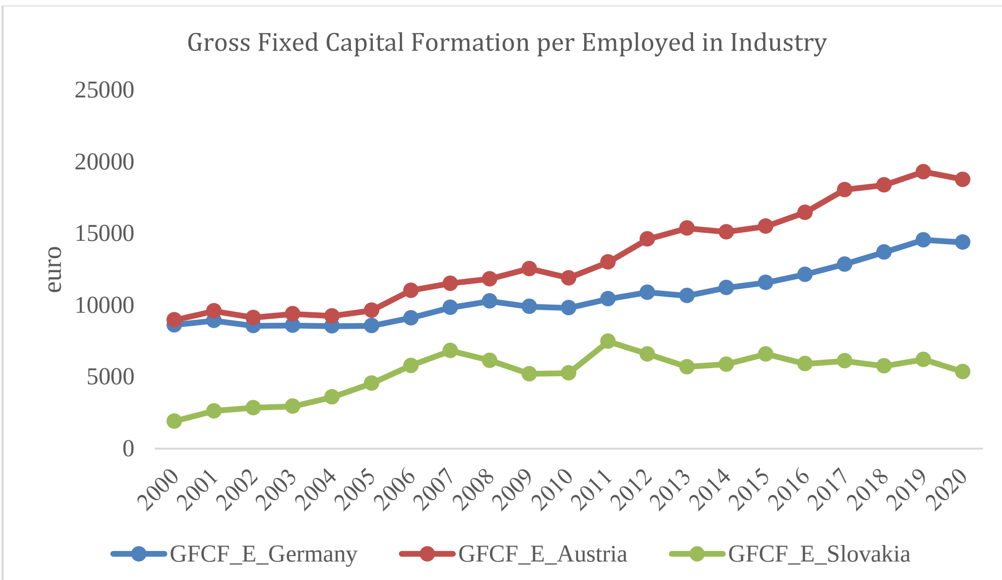


Figure: 1 Dynamics of GVA per Employed in Industry in Germany, Austria and Slovakia

Source: *Own Elaboration*

As can be seen from the graphs below, the indicators for these countries had a fairly stable upward trend, while the period of the global economic and financial crisis of 2008-2009 led to a slight decrease in the indicator values, which is noticeable in the graphs. The indicators of gross value added in industry per employee for Germany and Austria are quite close to each other, although the values of this indicator for Austria are slightly higher than for Germany. At the same time, a significant gap is clearly visible, more than 30,000 euros for similar indicators in Slovakia compared to Germany and Austria. In 2020, this gap was more than 40,000 euros.

Figure 2 presents graphs showing the dynamics of gross fixed capital formation in industry per employee in Germany, Austria and Slovakia. As can be seen from these graphs, the initial values of the indicators in Germany and Austria in 2000 were close, but later, there was a significant divergence of values. Thus, in Austria, the indicator of gross fixed capital formation in industry per employee increased significantly over time, while in Germany, the growth rates were significantly lower, which ultimately led to a gap in the values of this indicator compared to Austria. In Slovakia, the levels of gross fixed capital formation in industry per employee were significantly lower than similar figures in Germany and Austria. However, we can note a period of rapid growth in the indicator of gross capital investment in industry per employee, which was observed from 2000 to 2007. It was associated with intensive reforms in the Slovak economy and attracting large foreign investments for various large-scale projects in industry, primarily in the automotive industry and machinery building, engineering and robotics. Then, under the influence of the global economic and financial crisis of 2008-2009 and the increase in internal political conflicts and complications in the country's economy, from 2012 to 2019, the indicator of gross capital investment in the industry per employee remained almost at the same level, and in 2020 there was even a slight decrease in the value of this indicator.



Source: *Own Elaboration*

Figure 2: Dynamics of Gross Fixed Capital Formation per Employed in Industry in Germany, Austria and Slovakia

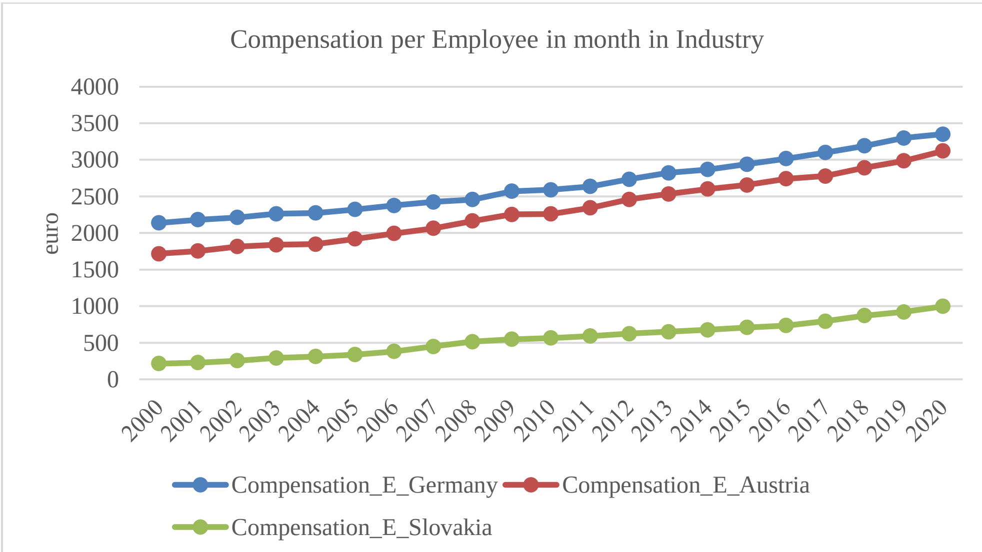
Fig. 3 shows the dynamics of growth in average wages in industry per employee (calculated per month) in Germany, Austria and Slovakia. As can be seen from the presented graphs for these countries, there is a steady upward trend in the values of these indicators. Germany had the highest average industrial wages per employee; the figures were somewhat lower in Austria. At the same time, in Slovakia, although the average wage in industry per employee increased, there remained a very strong gap in the level of these indicators compared to Germany and Austria. Thus, in 2020, the average wage in the industry per employee per month in Germany was more than 3,300 euros, and in Austria more than 3,100 euros. In Slovakia, it was at the level of 1,000 euros, i.e. more than 3 times less than in Germany or Austria.

Thus, on the basis of given results of graphical analysis of data presented in the form of time series for several important indicators of the level of industrial development in Germany, Austria and Slovakia, we can assume that simple deterministic trends are indicating an increase in indicators over time. In this regard, it is advisable to build simple forecasting models based on the use of linear trends to describe trends in changes in key industrial indicators in Germany, Austria and Slovakia.

As is known, a linear function describing a trend or development trend can be presented in the following form:

$$\widehat{y(t)} = a_0 + a_1 \cdot t,$$

where $\widehat{y(t)}$– is the simulated value of the indicator for time moment t, t is a time variable, with $t = 0\ (2000), t = 1(2001), t = 2(2002), \dots, etc.$ In this model, the unknown parameters a_0(intercept) and a_1(slope) are estimated using the ordinary least squares (OLS) method, and their statistical significance is tested using the Student and Fisher tests. When analyzing the constructed model, it is also necessary to calculate the deviations of real data from the simulated ones.



Source: *Own Elaboration*

Fig. 3 Dynamics of Compensation per Employed in Industry in Germany, Austria and Slovakia

The value $e(t) = y(t) - \widehat{y(t)}$indicates the deviation of the real values of the indicator y(t) from their simulated values $\widehat{y(t)}$. For linear trend models, the coefficient of determination $R^2$and correlation coefficient R are also calculated. The closer the value of the coefficients of determination and correlation is to 1, the better the quality of fit and the model with sufficiently high values of the coefficient of determination and correlation can be used for analysis and forecast. Table 2 shows the characteristics of constructing linear trend models for the main indicators characterizing the level of industrial development in Germany, Austria and Slovakia.

As can be seen from the calculation data given in Table 2, for the indicator of the number of people employed in industry in all three countries, there is a negative estimate for the parameter. a_1(slope). This means that for the period from 2000 to 2020, there was a decline in employment in the industry. At the same time, this trend was more complex than a simple linear function; therefore, the correlation and determination coefficients for these models are low. In this regard, it is advisable to use other forecasting models, for example, ARIMA.

Table 2: The estimation of the linear trend for the selected indicators for Industry in Germany, Austria and Slovakia for 2000-2020

	Germany			**Austria**			**Slovakia**		
	Intercept	**Slope**	**R**	**Intercept**	**Slope**	**R**	**Intercept**	**Slope**	**R**
Employed persons (EP)	12167906	-26448	-0,41	1179364	-3600,17	-0,66	982576,1	-2363,96	-0,36
Compensation in Industry (CI)	298480,9	8023,41	0,95	23049,66	868,46	0,98	2169,47	419,27	0,99
Gross fixed capital formation (CF)	93393,11	3287,48	0,9	9228,35	591,15	0,96	3370,6	160,11	0,67
Gross value added (GVA)	456313	15807,1	0,96	45757,91	1524,43	0,98	6559,75	790,72	0,96

Source: *Own Elaboration*

For other indicators, the estimates for slope are positive, and the correlation coefficient values are quite high and close to 1. The only exception is the linear trend model for the indicator CF in Slovakia, where the correlation coefficient is 0.67. However, as was shown earlier in the graph for this indicator, a more complex trend is observed.

Further, for the given indicators characterizing the level of industrial development in Germany, Austria and Slovakia, it is advisable to calculate pairwise correlation indicators. Pairwise correlation coefficients vary from -1 to 1. Negative values of pairwise correlation coefficients indicate the presence of a negative relation, i.e. as the value of one indicator increases, the value of the second indicator decreases. Positive values of pairwise correlation coefficients indicate the presence of a direct connection, i.e. with an increase in one indicator, an increase in the values of the second indicator is observed. A pairwise correlation coefficient equal to 0 or close to it in absolute value indicates the absence of a correlation between the two indicated indicators.

Table 3 presents calculations of paired correlation coefficients for the main indicators characterizing the level of industrial development in Germany, Austria and Slovakia. As can be seen, for all countries, the GVA, CF, and CI indicators have negative pairwise correlation coefficients with the EP indicator. This means that despite the decline in industrial employment in these countries, gross value added, gross fixed capital formation, and compensation were increasing or were not related to number of employed in industry.

Table 3: Correlation Matrix between the Selected Indicators for Industry in Germany, Austria and Slovakia

Germany					Austria					Slovakia				
	GVA	**CF**	**EP**	**CI**		**GVA**	**CF**	**EP**	**CI**		**GVA**	**CF**	**EP**	**CI**
GVA	1	0,95	-0,19	0,98	GVA	1	0,97	-0,54	0,98	GVA	1	0,83	-0,26	0,96
CF	0,95	1	-0,04	0,98	CF	0,97	1	-0,46	0,99	CF	0,83	1	-0,02	0,67
EP	-0,19	-0,04	1	-0,13	EP	-0,54	-0,46	1	-0,52	EP	-0,26	-0,02	1	-0,25
CI	0,98	0,98	-0,13	1	CI	0,98	0,99	-0,52	1	CI	0,96	0,67	-0,25	1

Source: *Own Elaboration*

To understand the nature of the relationship between individual indicators, it is advisable to build single-factor or multifactor regression models. This study analyzed the relationship between indicators of gross value added in industry per employee and indicators of gross fixed capital formation in industry per employee.

For modeling, a nonlinear model of the type $z(x) = e^{a_0 + a_1 \cdot x} = b_0 \cdot e^{a_1 \cdot x}$ was used, transformed then to linear form$y = a_0 + a_1 \cdot x$.

The characteristics of these models are given in the Table. 4.

Table 4: The Characteristics of the Econometric Models for Germany, Austria and Slovakia

Model	**Germany**			**Austria**			**Slovakia**		
$\boldsymbol{y = ln(GVA\_E)}$, $\boldsymbol{x = ln(GFCF\_E)}$	**Intercept**	**Slope**	**R**	**Intercept**	**Slope**	**R**	**Intercept**	**Slope**	**R**
$y = a_0 + a_1 \cdot x$	2,14	0,94	0,943	4,654	0,657	0,97	0,052	1,117	0,916

Source: *Own Elaboration*

As can be seen from the data in Table 4, for Germany and Austria, estimates of the parameter a_1 are less than 1, which corresponds to the classical Cobb-Douglas function, which considers the relation between the absolute values of gross value added (dependent variable) and factors - the number of employed and gross fixed capital formation. In the case of Slovakia, as well as many transformation countries, the estimate of the parameter a_1 is close to 1 or even exceeds it, and therefore, the estimates of the parameters in the Cobb-Douglas function will differ from the usual values.

To analyze the relationship between trends in changes in these indicators over time for Germany, Austria and Slovakia, paired correlation coefficients were calculated (Table 5). As you can see, the most interrelated trends are between the same indicators in Germany and Austria. The fairly high correlation between the trends of the indicators of the same name is explained by the significant historical, political, economic and cultural ties between these countries. The effect of the presence of a common border and the peculiarities of post-war development were important, as well as an influence of deep cooperation within the EU. At the same time, the trends between the same indicators in Germany and Slovakia are less related, which indicates some important economic and cultural differences: the absence of a common border, Slovakia's later accession to the EU and the transformation of the economy from a planned socialist model to a market model.

Table 5: Correlation Matrix for the Selected Indicators for Industry in Germany, Austria and Slovakia

Employed Persons				Compensation in Industry				Gross Fixed Capital Formation				Gross Value Added			
	EP_G	EP_A	EP_S		CI_G	CI_A	CI_S		CF_G	CF_A	CF_S		GVA_G	GVA_A	GVA_S
EP_G	1	0,86	0,68	CI_G	1	0,99	0,96	CF_G	1	0,97	0,48	GVA_G	1	0,98	0,92
EP_A	0,86	1	0,79	CI_A	0,99	1	0,99	CF_A	0,97	1	0,59	GVA_A	0,98	1	0,96
EP_S	0,68	0,79	1	CI_S	0,96	0,99	1	CF_S	0,48	0,59	1	GVA_S	0,92	0,96	1

Source: *Own Elaboration*

As was noted earlier, when conducting a comparative analysis of the level of industrial development, it is advisable to use relative indicators (coefficients) and percentages. Thus, it is advisable to calculate the share of gross value added obtained in the industry in relation to the gross value added in the economy as a whole. Similarly, similar ratios should be calculated for other indicators (number of employed, compensation and gross fixed capital formation).

Table 6 shows the calculation of the main statistical characteristics of these indicators. As can be seen from the above calculations, the share of gross value added obtained in industry fluctuated in Germany, Austria and Slovakia. Thus, the minimum value of this indicator in Germany was 23.42%, and the maximum value was 26.39%. In Austria, the minimum value of this indicator was 21.63%, and the maximum value was 24.46%. In Slovakia, the minimum value of the share of gross value added in industry was 22.98%, and the maximum value reached 30.99%. Similarly, a comparative analysis can be carried out for other indicators that show the contribution of industry to the overall development of the national economy.

Table 6: Descriptive statistics for some indicators for industry and its role in the economy in Germany, Austria and Slovakia

Indicator	Min	Max	Mean	Std.Dev.	Coef. variation	Max/Min
Germany						
Share GVA in Industry, %	23,42	26,39	25,32	0,69	2,74	1,13
Share GFCF in Industry, %	22,13	24,06	23,05	0,62	2,7	1,09
Share Compensation in Industry, %	24,74	29,19	27,54	1,18	4,28	1,18
Austria						
Share GVA in Industry, %	21,63	24,46	22,79	0,91	3,99	1,13
Share GFCF in Industry, %	18,77	23,34	21,23	1,37	6,46	1,24
Share Compensation in Industry, %	21,32	24,21	22,33	0,88	3,96	1,14
Slovakia						
Share GVA in Industry, %	22,98	30,99	26,59	2,24	8,43	1,35
Share GFCF in Industry, %	25,87	48,81	36,74	5,79	15,75	1,89
Share Compensation in Industry, %	24,76	29,4	27,08	1,38	5,1	1,19

Source: *Own Calculation*

Table 7 shows the results of statistical processing of the ratios of key indicators in industry and in the economy as a whole, per employed. Thus, relative coefficients were used whose values were less than, equal to, or greater than 1. Thus, if the value of the relative coefficient was greater than 1, then the corresponding indicator in the industry per employed was greater than the similar indicator in the economy as a whole. If the value of the relative coefficient was close to 1, then the corresponding indicator in industry per employed was approximately at the same level as the corresponding indicator in the economy as a whole. In the case of a relative coefficient value less than 1, it was clear that the corresponding indicator in the industry per employed is less than the corresponding indicator in the economy as a whole.

Table 7: Descriptive Statistics for Ratios in Industry and Total Economy in Germany, Austria and Slovakia

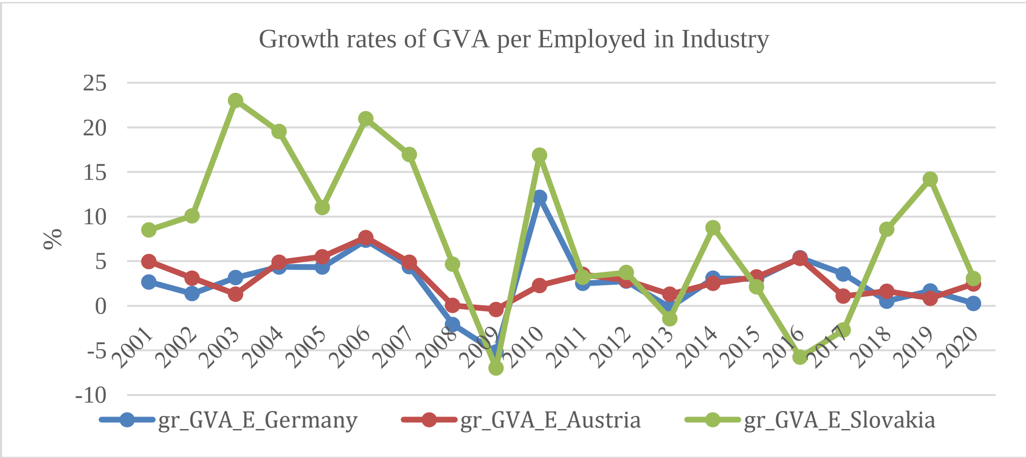
Indicator	Min	Max	Mean	Std.Dev.	Coef. variation	Max/Min
Germany						
GVA_per Employee Ratio	1,15	1,32	1,26	0,06	4,76	1,15
GFCF_per Employee Ratio	1,04	1,22	1,14	0,04	3,64	1,18
Compensation per Employee Ratio	1,13	1,19	1,16	0,02	1,88	1,06
Austria						
GVA_per Employee_Ratio	1,33	1,42	1,38	0,02	1,61	1,07

GFCF_per Employee_Ratio	1,1	1,47	1,28	0,12	9,47	1,34
Compensation_per Employee_Ratio	1,31	1,37	1,35	0,01	0,98	1,04
Slovakia						
GVA_per Employee_Ratio	0,98	1,19	1,07	0,06	5,36	1,21
GFCF_per Employee_Ratio	1,11	1,88	1,48	0,21	13,96	1,7
Compensation_per Employee_Ratio	1,05	1,15	1,09	0,03	2,75	1,1

Source: *Own Calculation*

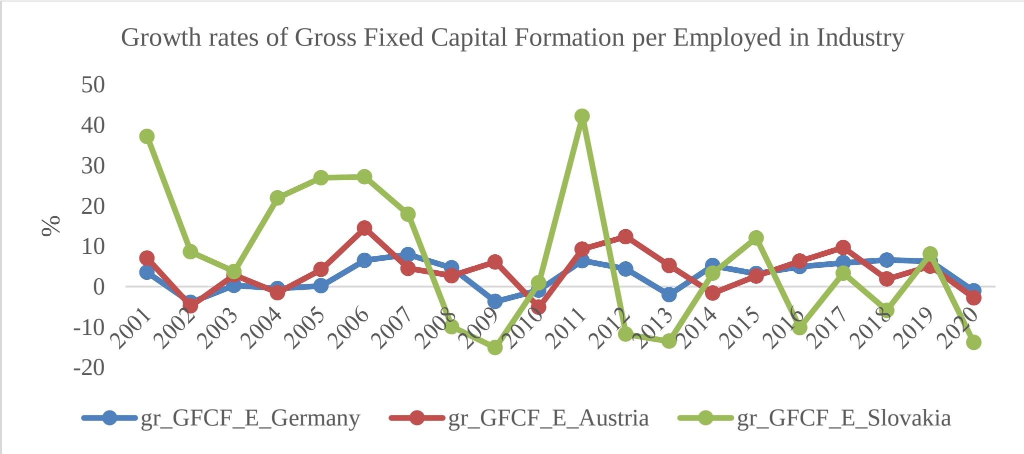
For Germany and Austria, it is clear that the average relative values for these indicators significantly exceeded 1. Thus, for Germany, on average, gross value added in industry per employee was 26% higher than the same indicator for industry as a whole. In Austria, on average, the same figure in industry was 38% higher than in the economy as a whole. In Slovakia, this difference averaged only 7%.

For a more detailed analysis of the dynamics of these indicators, it is necessary to calculate the annual growth rates and construct graphs. Fig. 4-6 show graphs of the growth rates of these indicators.



Source: *Own Elaboration*

Figure 4: Dynamics of growth rates for GVA per Employed in Industry in Germany, Austria and Slovakia

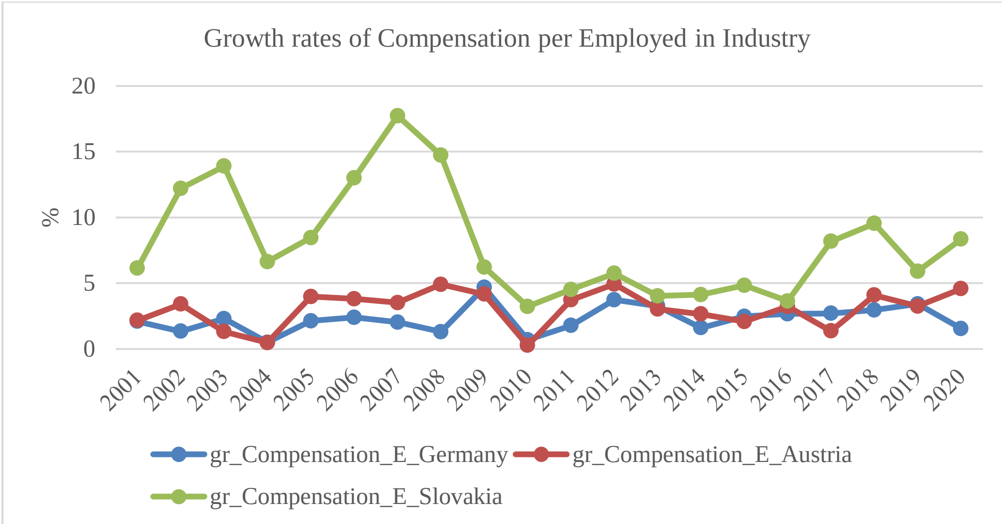


Source: *Own Elaboration*

Figure 5: Dynamics of growth rates for Gross Fixed Capital Formation per Employed in Industry in Germany, Austria and Slovakia

From those plots presented in Fig. 4-6, it is seen that the growth rates of these indicators in Germany and Austria changed slightly over time, and their variation was not too high. Negative growth rates were observed during the global economic and financial crisis of 2008-2009. The period of the COVID-19 pandemic had a negative impact on economic development in Germany and Austria, but it did not have such consequences as the 2008-2009 crisis.

At the same time, Slovakia demonstrated a very strong change in growth rates, which emphasized the more complex nature of development, especially during periods of large-scale economic reforms or during crises. Thus, the economic crisis of 2008-2009 and the pandemic period had a significant negative impact on the development of industry in Slovakia. The economy of Slovakia, like any other country that is in the stage of transformation and reform, turned out to be quite sensitive to various external and internal crises.



Source: *Own Elaboration*

Figure 6: Dynamics of Growth Rates Compensation per Employed in Industry in Germany, Austria and Slovakia

In Tables 8 and 9, calculations of paired correlation coefficients for the growth rates of these indicators for Germany, Austria and Slovakia were carried out. We analyzed pairwise correlations between the growth rates of various indicators for these countries and pairwise correlations between the growth rates of the same indicators for these countries.

Table 8: Correlation Matrix between the Growth Rates of Selected Indicators for Industry in Germany, Austria and Slovakia

Germany					Austria					Slovakia				
	τ_EP	τ_CI	τ_CF	τ_GVA		τ_EP	τ_CI	τ_CF	τ_GVA		τ_EP	τ_CI	τ_CF	τ_GVA
τ_EP	1	0,71	0,86	0,82	τ_EP	1	0,84	0,62	0,8	τ_EP	1	0,76	0,59	0,62
τ_CI	0,71	1	0,79	0,41	τ_CI	0,84	1	0,7	0,67	τ_CI	0,76	1	0,47	0,7
τ_CF	0,86	0,79	1	0,66	τ_CF	0,62	0,7	1	0,59	τ_CF	0,59	0,47	1	0,61
τ_GVA	0,82	0,41	0,66	1	τ_GVA	0,8	0,67	0,59	1	τ_GVA	0,62	0,7	0,61	1

Source: *Own Calculation*

Table 9: Correlation matrix for the growth rates of selected indicators for Industry in Germany, Austria and Slovakia

Employed persons				Compensation in Industry				Gross fixed capital formation				Gross value added			
	τEP G	τEP A	τEP S		τCI G	τCI A	τCI S		τCFG	τCFA	τCFS		τGV AG	τGVA A	τGVA S
τEPG	1	0,88	0,88	τCI G	1	0,71	0,23	τCFG	1	0,63	0,46	τGVAG	1	0,8	0,66
τEPA	0,8 8	1	0,89	τCI A	0,71	1	0,64	τCFA	0,63	1	0,37	τGVAA	0,8	1	0,68
τEPS	0,8 8	0,89	1	τCIS	0,23	0,64	1	τCFS	0,46	0,37	1	τGVAS	0,66	0,68	1

Source: *Own Elaboration*

In general, the coefficients of paired correlations for many indicators are quite high, which also indicates general tendencies in changes in the indicators given in Tables 8 and 9.

It should be noted that a simple comparative analysis of indicators, which characterized the level of industrial development in Germany, Austria and Slovakia, does not give a complete general idea about the situation and the nature of its changes as a whole. Therefore, when conducting a comparative analysis in the case of several indicators, it is advisable to use cluster analysis or various aggregated indices.

Table 10 shows the results of a cluster analysis of a data array characterizing various specific indicators calculated per employed in industry and relative indicators characterizing a comparison of the level of industrial development and its impact on the economy as a whole. Previously, these indicators were considered in the previous stage of the study, and the results of their statistical processing are shown in Tables 6 and 7 and dynamics are shown in Figures 1-3.

Table 10: The Results of the Cluster Analysis for Grouping Cases of Industrial Development in Germany, Austria and Slovakia

	Cluster 1		Cluster 2		Cluster 3		Cluster 4		Cluster 5	
	Mean	**St.Dev.**	**Mean**	**St.Dev.**	**Mean**	**St.Dev.**	**Mean**	**St.Dev.**	**Mean**	**St.Dev.**
V1	15172,93	5526,877	41704,77	2823,092	51690,88	2193,896	57920,87	2148,428	64906,73	1343,928
V2	5195,32	1539,937	9045,06	471,802	10815,67	1002,634	13556,07	1782,503	16264,91	2446,410
V3	556,24	235,042	2065,68	265,444	2397,90	263,093	2676,97	240,804	3050,15	217,449
V4	26,59	2,242	24,36	0,792	24,68	1,534	23,48	1,801	23,30	1,727
V5	36,74	5,788	21,73	2,056	21,91	1,185	22,45	0,709	22,77	0,672
V6	27,07	1,381	26,18	2,660	25,49	2,977	23,83	2,622	23,38	2,286
V7	1,07	0,057	1,27	0,099	1,34	0,056	1,34	0,040	1,34	0,052
V8	1,48	0,206	1,12	0,042	1,19	0,066	1,29	0,119	1,31	0,124
V9	1,09	0,030	1,24	0,110	1,25	0,085	1,28	0,096	1,26	0,102

Source: *Own Calculation*

Table 11 shows the results of cluster analysis for data from three countries, Germany, Austria and Slovakia, for the period 2000-2020. From the results given in Table 11 it is clear that Germany and Austria were in clusters 2-5, while Slovakia was in cluster 1 throughout the entire period. The results obtained confirm our assumptions that Germany and Austria are countries close in level of industrial development, although some differences in dynamics were observed. At the same time, the level of industrial development in Slovakia differs significantly from Germany and Austria. Therefore, Slovakia is in a separate cluster.

Table 11: The distribution of the industrial development cases into clusters

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Slovakia (2000-2020)	Germany (2000-2005), 2009	Germany (2006-2008), (2010-2012)	Germany (2014-2016)	Germany (2017-2020)
	Austria (2000-2005)	Austria (2006-2010)	Austria (2011-2015)	Austria (2016-2020)

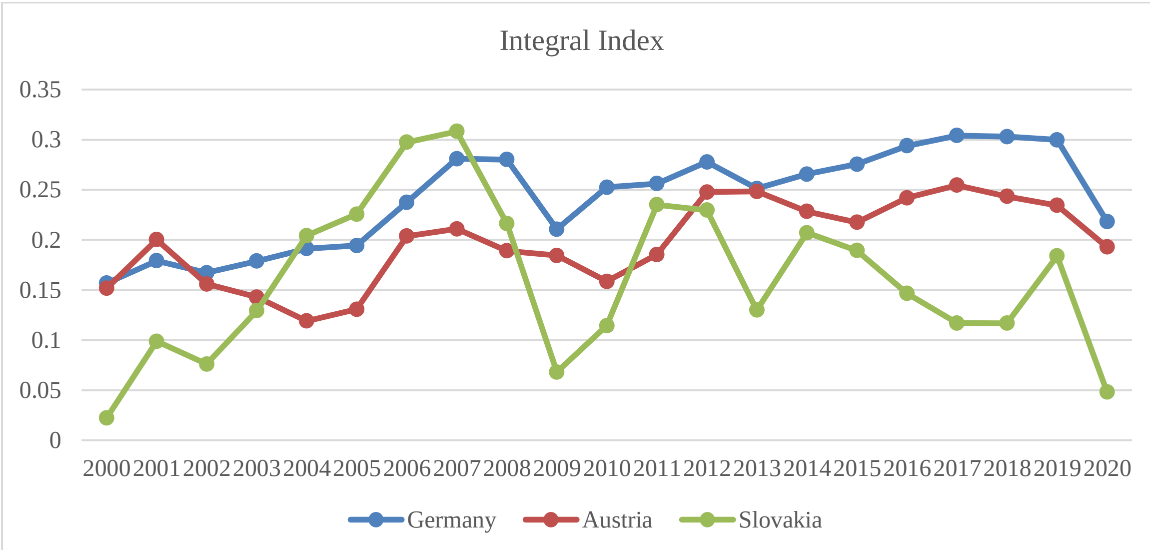
Source: *Own Calculation*

For some studies, the method of convolution of the values of particular indicators into a general aggregate indicator is used. In such studies, it is important to understand the general level of industrial development as some general indicator that characterizes certain qualities as a whole. There are various convolution methods, from the use of simple scales and the calculation of weighted averages to more complex approaches that take into account the distance from some artificial standard or point in multidimensional space. These methods include the approach developed by the Polish scientist Helwig and presented in the works of Pluta (1980) and Mlodak (2006), as well as other scientists.

In the method developed by Helwig, an artificial standard is selected from the best values of indicators characterizing development. Thus, in the array of standardized values of indicators V1-V9 for the indicated countries for the period 2000-2020, the maximum values (standard) are selected, and the distance values for each observation from the artificial standard are calculated. Then, a simple transformation of the distance values is carried out using a new scale from 0 to 1. The closer the value of the integral indicator calculated in this way is to 1, the higher the level of development or the closer its value is to the ideal state or standard.

In Fig. 7 it shows the dynamics of the integral index for Germany, Austria and Slovakia. It is clear for Germany and Austria that the dynamics of integral indices of industrial development, reflecting the nonlinear nature of trends, are still more stable. This is the expected effect for countries with stable economies and developed legislative and institutional relationships. In Slovakia, on the contrary, large jumps in the integral index are visible. It was especially seen during the period of massive reforms when this index increased sharply and reached a maximum in 2007. Then there was a dramatic decline, then some fluctuations and finally a period of rapid decline from 2014 to 2018, and then a fall in the period of the COVID-19 crisis.

Autoregressive and moving average models (ARMA) are used to simulate such complex nonlinear trends. In this case, ARIMA models were also used. The characteristics of these models are given in Table 12. As follows from the calculation results in Table 12, in ARIMA models for data from Germany and Austria, the parameter estimates for the constant and the first lagged value of the integral indicator were statistically significant. At the same time, a more complex development trend was observed for Slovakia, and only the constant in the ARIMA model was statistically significant.



Source: *Own Calculation*

Figure 7: Dynamics of Integral Indexes of Industrial Development for Germany, Austria and Slovakia

Table 12: The application of ARIMA for the modeling of the dynamics of integral indexes of Industrial Development for Germany, Austria and Slovakia

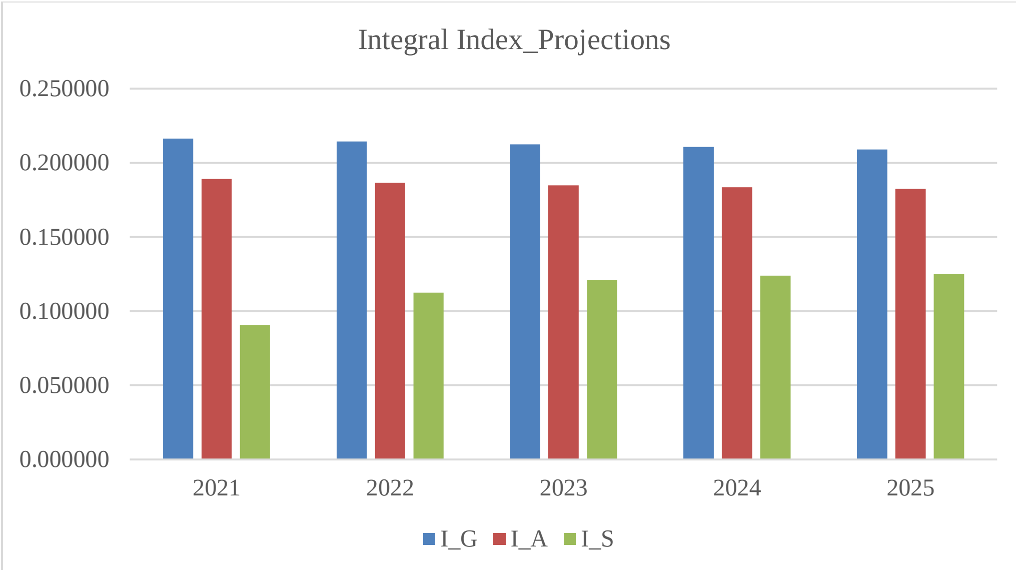
Germany						
Input: I_G Transformations: ln(x) Model:(1,0,0) MS Residual= 0,01783						
	Param.	**Asympt. Std. dev.**	**t-Asympt.**	**p**	**Lower value**	**Upper value**
Constant	-1,83608	0,148035	-12,4030	0,000000	-2,14592	-1,52624
p(1)	0,97021	0,073868	13,1344	0,000000	0,81560	1,12482
Austria						
Input: I_A Transformations: ln(x) Model:(1,0,0) MS Residual= 0,02841						
	Param.	**Asympt. Std. dev.**	**t-Asympt.**	**p**	**Lower value**	**Upper value**
Constant	-1,71419	0,133962	-12,7961	0,000000	-1,99458	-1,43381
p(1)	0,72075	0,203102	3,5487	0,002144	0,29566	1,14585
Slovakia						
Input: I_S Transformations: ln(x) Model:(1,0,0) MS Residual= 0,39619						
	Param.	**Asympt. Std. dev.**	**t-Asympt.**	**p**	**Lower value**	**Upper value**
Constant	-2,07533	0,243890	-8,50928	0,000000	-2,58579	-1,56486
p(1)	0,34011	0,277850	1,22409	0,235881	-0,24143	0,92166

Source: *Own Calculation*

Based on the models presented in Table 12, the forecasts were obtained for the period 2020-2025. These results demonstrate the values of integral indicators characterizing the dynamics of industrial development for the next 5 years.

The forecast results are presented in Figure 8.

From the graphs shown in Figure 8, it is clearly seen that the values of the integral indicator characterizing the level of industrial development in Germany and Austria will be quite stable without significant changes. At the same time, in Slovakia there will be a growth trend in the period 2021-2023 and then subsequent stabilization.



Source: *Own Calculation*

Figure 8: Forecasts for Integral Index of Industrial Development for Germany, Austria and Slovakia for 2021-2025, according to ARIMA

IV. CONCLUSION

Thus, when conducting a comparative analysis of the level of industrial development in different countries, it is advisable to use not only simple methods such as descriptive statistics or visual analysis of graphs but also more complex approaches that allow a comprehensive study of indicators, their dynamics, and features of trends, which are often nonlinear in nature. The linear trend models and nonlinear regressions were built for the description of the main indicators characterizing the industrial development in Germany, Austria and Slovakia. In this research, multidimensional statistics and qualitative indicators such as integral index were introduced for the description of the states or regimes of the development of industry in the mentioned countries.

Nevertheless, it should be noted that other models, such as VAR (vector autoregressive models) or spatial econometrics models, can be used. In VAR models, the nonlinear dynamics and impulse effect are to be tested, and in spatial econometrics models, the complicated temporal and spatial effects can be revealed. Similar studies of industrial development should be carried out for other countries of the EU, and the impact of the industry on the formation of GDP and employment policy should be analyzed. The necessity for reindustrialization and the variations in the industrial base development among EU Member States should be considered in the industrial policy. Therefore, it should provide tools that are suited to the requirements of the relevant industries and regions, enhancing the competitiveness of the entire European Union. It must support the digital transformation of industrial production techniques through a financing program for digital transformation and with a focus on a skilled labor force, which gives it a competitive edge over other regions of the world economy.

Interest Conflicts

The authors declare that there is no conflict of interest concerning the publishing of this paper.

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V. REFERENCES

[1] A Digital Strategy 2025. (2016). Federal Ministry for Economic Affairs and Energy (BMWi). April 2016.

[2] Alcácer, V., Cruz-Machado, V. (2019). Scanning the Industry 4.0: a literature review on technologies for manufacturing systems. Eng. Sci. Technol. Int. J., 22 (3) (2019), pp. 899-919.

[3] Banholzer, V. M. (2022). From „Industry 4.0“ to „Society 5.0“ and „Industry 5.0“: Value- and Mission-Oriented Policies: Technological and Social Innovations – Aspects of Systemic Transformation. IKOM WP Vol. 3, No. 2/2022. Nürnberg: Technische Hochschule Nürnberg Georg Simon Ohm.

[4] Bardeau, F. (2017). Youth, Skills and the Workforce of the Future. Cambridge, MA: MIT–Solve. Available at: https://solve.mit.edu/challenges/youth-skills-the-workforce-of-the-future/solutions/2019.

[5] Bortolini, M. et al. (2017). Assembly system design in the Industry 4.0 era: a general framework. IFAC-PapersOnLine, 50 (1) (2017), pp. 5700-5705

[6] Bown, Ch. P. (2023). Modern industrial policy and the WTO. Working paper. Peterson Institute for International Economics (PIIE), USA.

[7] Cameron, R. (1985). A New View of European Industrialization. The Economic History Review, 38(1), 1–23. https://doi.org/10.2307/2596641

[8] Chapter 5. Energy Crisis and structural change: Prospects for German industry (2023). In: Annual Report 2022/23 – German Council of Economic Experts. pp. 209-272.

[9] Chen, Y., Lan, T., Mineshima, A., and Zhou, J. (2023). Impact of High Energy Prices on Germany's Potential Output. IMF Selected Issues Paper (SIP/2023/059). Washington, DC.

[10] Dauth, W., Findeisen, S., Südekum, J. (2017). German Robots – The Impact of Industrial Robots on Workers. In: IAB Discussion Paper Articles on labour market issues 30/2017.

[11] Deutsche Bundesbank Monthly Report December 2022. Outlook for the German economy for 2023 to 2025. Available at: https://www.bundesbank.de/resource/blob/901990/90afad2737f689d42ac53510149cc0de/mL/2022-12-prognose-data.pdf

[12] Dubrovina, N., Hudakova, M, Graser, S., Grimberger, V. (2022). Education, innovations and development of local markets in CEE countries: problems and perspectives, Przegląd Europejski, ISSN: 1641-2478 vol. 2022, no. 4.

[13] Hancké, B., Coulter S. (2013). The German manufacturing sector unpacked: institutions, policies and future trajectories. Future of Manufacturing Project: Evidence Paper 13. Foresight, Government Office for Science, UK.

[14] Homma, T. (2021). Contemporary Agenda on Industrial Development and Policy Support to Developing Countries. JICA (Japan International Cooperation Agency), 2021.

[15] Jewkes, J. (1951). The Growth of World Industry. Oxford Economic Papers, 3(1), 1–15. http://www.jstor.org/stable/2662110

[16] Lall, S. (1991). Explaining Industrial Success in the Developing World. In: Balasubramanyam, V.N., Lall, S. (eds) Current Issues in Development Economics. Current Issues in Economics. Palgrave, London. https://doi.org/10.1007/978-1-349-21587-4_7

[17] Masood, T., Egger J. (2019). Augmented reality in support of Industry 4.0—Implementation challenges and success factors Robot. Comput. Integr. Manuf., 58 (2019), pp. 181-195.

[18] Młodak A. (2006). Analiza taksonomiczna w statystyce regionalnej. Warszawa, Wydawnictwo Difin, 2006

[19] Mouzakitis, G.S. (2010). The role of vocational education and training curricula in economic development. Procedia Social and Behavioral Sciences 2 (2010) 3914–3920.

[20] Mühlberger, M., Boettcher, B., Walther, U. (2021). Germany in the next decade: Ambition and potential. In: Germany Monitor. Deutsche Bank Research. March 9, 2021.

[21] Naqshbandi, M. M, Jasimuddin, S. M. (2018). Knowledge-oriented leadership and open innovation: role of knowledge management capability in France-based multinationals. Int. Bus. Rev., 27 (3) (2018), pp. 701-713.

[22] Petrovski, V. (2011). Contemporary modern industrial societies and the role of education. Procedia Social and Behavioral Sciences 15 (2011) 1362–1365.

[23] Plyuta V. (1980). Compared multidimentional analysis in economic researches.-M., Statistica, 1980

[24] Pollard, S. (1973). Industrialization and the European Economy. The Economic History Review, 26(4), 636–648. https://doi.org/10.2307/2593702

[25] Regnerova, O., Šálková, D., Šánová, P. (2021). The Importance of Industry in Modern Economies of the Globalized World in the 21st Century. HS Web of Conferences 92, 0 (2021) Globalization and its Socioeconomic Consequences 2020. https://doi.org/10.1051/shsconf/20219204021

[26] Schneider, E. (2023) Germany's Industrial strategy 2030, EU competition policy and the Crisis of New Constitutionalism. (Geo-) Political economy of a contested paradigm shift, New Political Economy, 28:2, 241-258, doi: 10.1080/13563467.2022.2091535

[27] Segovia, M.C., Checa M.C. (2021). Education and training for rapidly evolving labour markets.

[28] Seifert, I., Bürger, M., Wangler, L. et al. (2018). Potential of artificial intelligence in Germany's producing sector. PAiCE, Berlin, 2018.

[29] Vitols, Sigurt (1996): German industrial policy: An overview, WZB. Discussion Paper, No. FS I 96-321, Wissenschaftszentrum Berlin für Sozialforschung (WZB), Berlin