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Optimisation of structural parameters of the industry by the criterion of product innovation

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ABSTRACT
The industrial sector of the Polish economy plays an important role in ensuring the socio-economic development of the country. The Polish industry accounts for 24.1 % of the country's employed population and 25.1 % of the GVA. The article aims to model the structural parameters of the Polish industrial sector according to the criterion of increasing product innovation level based on a comprehensive assessment of the Polish industry performance in the regional context. The offered method focuses on estimating the industrial sector at the macro and meso levels using a set of indicators for investment, innovation, labour activity, and profitability. Correlation-regression analysis methods were used to prove hypotheses about the impact of product innovation on employment and wages in the industry. To optimise the structure of the Polish industrial sector, an economic-mathematical model was developed, which was solved using the linear programming method. The target functionality of this model is the level of product innovation, at which the gross average monthly wage of Polish industry workers will double (to the EU average). The simulation results, which was based on data from the Central Statistical Office of Poland, provide an analytical basis for selecting industrial policy benchmarks for Poland.

KEY WORDS
industry, efficiency, product innovation, production, models, structure, optimisation

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Introduction

Industry is an important sector of the European Union's (EU) economy. In Poland, it accounts for 24.1 % of the employed population and 25.1 % of the gross value added (GVA). The industry also plays a key role in ensuring the competitiveness of EU countries, as it accounts for about 60 % of merchandise exports (on average in the EU-28).

Today, according to the European Classification of Economic Activities NACE Rev.2, the industry

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includes the following types of industrial activity: mining and quarrying; processing industry manufacturing (which consisting of 36 productions); electricity, gas, steam and air conditioning supply, water supply; sewerage, waste management and remediation activities. The industry operation is influenced by a large number of different dynamic (or rapidly changing) factors. It is, e.g., world market conditions, access to foreign commodity and raw materials markets, global competition and concentration of products, and force majeure. One of the most important dynamic factors hindering the development of the industrial sector of the economy in 2020 was quarantine restrictions imposed by governments to curb the spread of the COVID-19 pandemic. In the first half of 2020, compared to the same period of 2019, Poland saw a decrease in the volume of industrial production to 6.8 percentage points (pp). The decline in industrial production occurred in 15 of the 16 regions of the country.

1. Literature review

In addition to dynamic factors, the results of industrial functioning are significantly (and in some cases decisively) influenced by relatively stable factors, including the scale of production, adequacy and efficiency of capital investment, innovation of industrial products, and labour productivity. These categories are both factors and results of the industrial sector functioning. The results of each category analysis and comprehensive assessment generally form the basis for diagnosing problems and prospects of the industry. Such a basis can be used to develop managerial tactical and strategic decisions to regulate the macro and meso levels of the industrial sector towards targeted restructuring. This article is a logical continuation and further expansion of the author's research results aiming to update issues of the industrial sector competitiveness, substantiate ways to increase socio-economic efficiency of the industry in EU countries and optimise the structure of the manufacturing industry. Ishchuk (2018) and Sozansky (2018 a, 2018 b, 2017) developed and tested an original methodology for assessing the industry's competitive advantages in Ukrainian regions, based on a comprehensive system of indicators characterising key aspects, results and factors of the industry. The main applied results of this methodology were: rating and grouping of regions of Ukraine by values of integrated activity indicators (production, capital, investment, innovation, and export) and industry efficiency (economic and resource), identifying competitive advantages and weaknesses of the industrial sector of the economy in 24 Ukrainian regions.

Another critical research result was to identify the transformational trend of the industrial sector of Ukraine's economy in the regional context. The essence of this trend is the formation of new industrial centres that are still small but have higher (compared to the old industrial regions) economic efficiency indicators for industrial enterprises, labour productivity, the level of manufacturability and innovation. Such new industrial centres are primarily located in regions with high unemployment and low wages. The industry priorities in these regions are manufacturing products with a relatively higher share of GVA and the degree of processing of raw materials, reducing the resource intensity of products and their high export orientation, particularly to EU markets. In addition, the method was used to make a comparative assessment of the competitive advantages of Ukrainian and Polish industries at the macro level and the Lviv region and Subcarpathia Voivodeship at the meso level.

Therefore, it became relevant to consider the developed methodology's universality for assessing the industrial sector's functioning in other countries, including the EU. One of the reasons was the variety of approaches used by the industry to choose indicators and algorithms for their analysis. Pla-Barber and Villar (2019) conducted a quantitative assessment of companies of the Spanish automotive and textile industries in the context of GVA chains and determined the shares of sales, GVA, average wages per employee and employment.

An assessment of structural changes in the Czech economy in 1996–2002 using the DSGE (dynamic stochastic general equilibrium) model, estimated with Bayesian methods, is given by Čapek (2016). Wlodarczyk (2013) provided an overview of structural changes in the Polish food industry in 2000–2012 and used nonlinear programming methods to optimise the structure of production factors. Kudełko (2016) assessed the industry's role in the economy of Polish regions and calculated indicators of the industry's share in sales, employment, and region's GVA. At the same time, the study of the industrial sector of the Polish economy ignored the issue of its comprehensive assessment in the regional context. Few publications on this topic considered some, the most important aspects of economic activity or key industry sectors. Also, these and the other studies paid insufficient attention to modelling the impact of structural parameters of the processing industry on its efficiency (economic and social). In addition, research on this topic rarely uses a comprehensive scientific approach, which covers the whole spectrum from problem argumentation, proposing and confirming hypotheses, to justification and testing through modelling.

An essential component and indicator of industrial development is the innovation of its products. Kongaut and Bohlin (2017) found that broadband speeds had a positive effect on the gross domestic product, and this effect was higher in lower-income countries. According to Dąbrowski (2018), market information received from consumers and businesses (excluding competitors) has a positive effect on product innovation. Kotowicz-Jawor (2019) analysed the relationship between the current developmental stage of the Polish economy and the determinants of its innovation potential in the context of the EU structural funds. An important result of this study was the assertion that the economic growth of the Polish economy depended more on external funding sources (EU funds, foreign investment) than on the domestic innovation potential. Pidorycheva and Kovchuha (2019) determined that the total amount of innovation costs was somewhat closely related to the volume of sold innovative products.

To assess the industry's innovativeness in Lower Silesia Voivodeship, Brezdeń and Spallek (2013) calculated the following indicators of innovation: innovation activity, expenditures on innovations, income, type of products (new or improved), and production equipment. These indicators were integrated into the synthetic indicator. The innovativeness of Polish voivodships was calculated using a synthetic indicator consisting of indicators derived by Janiszewska and Ossowska (2017). The synthetic indicator was used as the basis to determine the regions with the highest and the lowest levels of innovation. The assessment of the road transport development in Polish voivodships and its impact on the socio-economic indicators of the region was carried out using a taxonomic indicator and econometric analysis as highlighted by Czech and Lewczuk (2016).

The reviewed research highlighting the innovation of the Polish industry showed insufficient attention paid to the following aspects.

Product innovation in combination with other interrelated indicators that reflect the economic conditions for innovation and the consequences (impact) of innovation on the economic performance of enterprises in Poland and its regions were studied by Lubacha (2019), Golejewska (2018), Zakrzewska and Chojnacki (2020), Chybowska, Chybowski and Souchkov (2018), and Węglarz (2018). Product innovation research without a parallel assessment of other direct links of economic activity in industrial enterprises fails to reflect the impact of economic preconditions on innovation and socio-economic situation and performance results of enterprises in the region.

Many studies into a comprehensive economic activity assessment of the economy's real sector in Polish regions, such as by Adamowicz (2021), Miłek and Mistachowicz (2019), Tereszczuk (2015), and Gajda (2016), consider the current state of investigated processes for the last year or three, but usually disregard transformation processes, dynamic changes occurring over certain cycles, and larger time measurement ranges. Failure to consider such more global changes makes it is impossible to weigh prospects and make an objective assessment of global and transformational processes, which are important when considering the economic activity in the regions.

The studies assessing the economic processes of Polish regions use integrated taxonomic and consolidated indicators for the study period. Majka and Jankowska (2017), Godinho, Mendonça and Pereira (2005), and Lubacha (2019) mainly analysed the current state for the selected years. Dynamic indicators, and especially those with a reasonably long period of cyclical, structural or transformational changes, are not considered or included as components of integrated indicators.

Some studies, such as by Bierut (2016, pp. 79-82), Piłka (2019, p. 28), Karpińska (2018, p. 227), Karpińska and Protasiewicz (2019), assume or theorise about the relationship between innovation and workers' wages, innovation and employment. However, no available and reviewed resources were found to provide the numerical expression of the closeness of such relationships, their directions, statistical characteristics on the example of the Polish industry or other economic sectors. The substantiation and quantitative and qualitative characteristics of such relationships are the basis for forecasting, research, modelling and stimulation of many socio-economic and financial processes. Information about the relationship between innovation and wages and possible investment in innovation can help determine the dynamics of migration processes and, thus, the key socio-economic indicators used to calculate tax revenues and expenditures of regional and central budgets and business activity indicators of the studied sectors.

The topic of structural parameter optimisation in the Polish industry was not reflected in the reviewed scientific research. At the same time, one of the most relevant aspects of the macroeconomic regulation and stimulation of the country's industrial development is the identification of industrial production that can give the greatest multiplier effect on the national socio-economic development due to higher product innovation. Therefore, such information can contribute to more rational use and attraction of investment resources or financial support. As innovation in modern conditions is the most important driver for the national socio-economic development, it justifies the need to optimise the volume of sold industrial products (as one of the key structural parameters) by the criterion of innovation. Therefore, the following economic model construction is substantiated as it will show the structure of sold industrial products required to achieve the desired level of innovation and other social indicators, such as the desired average wage, employment and macroeconomic components (dynamics of labour migration, income and expenditure to budgets, etc.).

Therefore, this study was relevant and also directed to address the identified theoretical and methodological and practical gaps in addition to practical aspects.

The article aims to model the structural parameters of the industrial sector of the Polish economy by the criterion of increased product innovation level based on a comprehensive assessment of the Polish industry operation in the regional context.

2. Methodology

The article presents an original method of a comprehensive assessment of trends and results of the industrial sector of the economy at the macro and meso levels. It is formed according to the principles and approaches of the methodology tested on the example of Ukraine (Ishchuk, 2018), but at the same time, it is improved and expanded to fit the purpose of this study, based on indicators that can be calculated from open statistics.

The algorithm for implementing the developed methodology includes three main stages.

The first stage involves calculating the level of industrialisation and innovation of the country's economy in terms of its regions. The method proposes to determine the economy's level of industrialisation and innovation at the meso level by indicators of the industry's share in each of the regions in key absolute indicators of the industrial sector. These indicators include the volume of sold industrial products, the GVA industry, the cost of innovative activities of industrial enterprises, and the net income from the sale of innovative products. The relevant regional structures are built based on calculated results of the region's share in these indicators for the selected period (ten years). Such structures clearly demonstrate the current level and dynamics of industrialisation and innovation of the regional economy.

The second stage involves an integrated assessment of the industrial sector's efficiency at the macro and meso levels. The algorithm for implementing this step is schematically presented in Table 1.

A detailed applied analytical research and expert-logical approach resulted in investment, labour and innovation activity, and profitability determined as the most important indicators of industrial functioning from the standpoint of economic and social efficiency and development prospects. These indicators are both results and factors in the industry functioning as they are closely interrelated.

Twelve indicators were selected for the analysis to comprehensively reflect the results of the industrial sector's functioning at the macro and meso levels. Each of these indicators is a stimulant, i.e., the higher the value of the indicator, the higher the result of the activity it characterises. The selected indicators can be calculated from open statistics.

In addition, the authors propose to assess the effectiveness of the industrial sector both by current values of the selected indicators and by indices of the dynamics of these indicators (for a period of ten years). This will allow to compare the current (actual) and previous levels of the industry's efficiency in the country and its regions and to diagnose the change trend in this level.

Hellwig method was used to bring the multidimensional values of the selected indicators-stimulators into a comparable form (Hellwig, 1968):

The application of formula (1) allows placing all the actual values of the indicators listed in Table 1

$$Y = \frac{Z_{ij} - Z_{min}}{Zmin_{max}} \quad (1)$$

where:

Y – the normalised indicator-stimulator;

Z_{ij} – the actual value of the i-th indicator in the j-th region

Z_{min} – the minimum value of the i-th indicator in the sample (study regions)

Z_{max} – the maximum value of the i-th indicator in the sample

Tab. 1. Efficiency indicators of the industrial sector

Performance indicators	**The indicators of the current state**	**The indicators of dynamics (for a period of 10 years)**
Investment activity	The investment outlays per one employee (x_1^{kf})	The index of investment expenditures per employee (x_1^{kd})
	The value of investment outlays per one employee (x_2^{kf})	The index of the value of investment outlays per employee (x_2^{kd})
	The expenditures on innovation activity per one employee (x_3^{kf})	The index of expenditures on innovation activity per employee (x_3^{kd})
	The taxonomic indicator of current investment activity $X^{kf} = (x_1^{kf} + x_2^{kf} + x_3^{kf})/3$	The taxonomic indicator of the dynamics of investment activity $X^{kd} = (x_1^{kd} + x_2^{kd} + x_3^{kd})/3$
The general taxonomic indicator of investment activity $X^k = (X^{kf} + X^{kd})/2$		
Labour activity	The GVA per employee in the industry (x_1^{lf})	The index of GVA per employee in the industry (x_1^{ld})
	The sold production of industry per employee (x_2^{lf})	The index of sold production of industry per employee (x_2^{td})
	The gross monthly average salary of the employed (x_3^{lf})	The index of the gross monthly average salary of the employed (x_3^{ld})
	The taxonomic indicator of the current labour activity $X^{lf} = (x_1^{lf} + x_2^{lf} + x_3^{lf})/3$	The taxonomic indicator of the dynamics of labour activity $X^{ld} = (x_1^{ld} + x_2^{ld} + x_3^{ld})/3$
	The general taxonomic indicator of labour activity $X^L = (X^{lf} + X^{ld})/2$	
Innovative activity	The share of net revenues from the sale of innovative products in the net revenues from the sale of industrial enterprises in general (x_1^{if})	The index of the share of net revenues from the sale of innovative products in the net revenues from the sale of industrial enterprises in general (x_1^{id})
	The share of net revenues from the sale of innovative products for the market in the net revenues from the sale of industrial enterprises in general (x_2^{if})	The index of the share of net revenues from the sale of innovative products for the market in the net revenues from the sale of industrial enterprises in general (x_2^{id})
	The share of net revenues from the sale of innovative products for the market for a market on export in the net revenues from the sale of industrial enterprises in general (x_3^{if})	The index of the share of net revenues from the sale of innovative products for the market for a market on export in the net revenues from the sale of industrial enterprises in general (x_3^{id})
	The taxonomic indicator of current innovation activity $X^{if} = (x_1^{if} + x_2^{if} + x_3^{if})/3$	The taxonomic indicator of the dynamics of innovation activity $X^{id} = (x_1^{id} + x_2^{id} + x_3^{id})/3$
	The general taxonomic indicator of innovation activity $X^I = (X^{if} + X^{id})/2$	
Profitability of activity	The profitability on assets (x_1^{pf})	The index of the profitability on assets (x_1^{pd})
	*The profitability of products of the employed (x_2^{pf})	*The index of the profitability of products of the employed (x_2^{pd})
	The profitability on turnover (x_3^{pf})	The index of profitability on turnover (x_3^{pd})
	The taxonomic indicator of current economic efficiency $X^{pf} = (x_1^{pf} + x_2^{pf} + x_3^{pf})/3$	The taxonomic indicator of the dynamics of economic efficiency $X^{pd} = (x_1^{pd} + x_2^{pd} + x_3^{pd})/3$
	The general taxonomic indicator of profitability $X^P = (X^{pf} + X^{pd})/2$	
The integral indicator of the current state $I^f = \sqrt[4]{X^{kf} X^{lf} X^{if} X^{pf}}$		The integral indicator of dynamics $I^d = \sqrt[4]{X^{kd} X^{ld} X^{id} X^{pd}}$
The final integrated indicator of the industry's efficiency $I = \sqrt[4]{X^K X^L X^I X^P}$		

*The profitability of products of the employed — the indicator, calculated as the ratio of the net financial result per employee in the industry to the average annual salary of the employed in the industry into the range from 0 to 1. The regions with the highest value of each indicator will correspond to the maximum level of 1, and with the minimum of 0. Thus, all regions for each indicator will be placed in the order of distance from the region with the maximum value of the indicator.

For each of the four selected performance indicators (investment, labour, innovation and profitability), the calculation of taxonomic indicators of the current state and dynamics, which are defined as the arithmetic mean of the three standardised indicators for each indicator. General taxonomic indicators are calculated as the arithmetic mean of taxonomic indicators of the current state and dynamics. The integrated indicator of the current state is defined as the geometric mean of four taxonomic indicators of the current state (for each of the four efficiency indicators).

The third stage of the study involves ranking the regions by values of integrated indicators of the current state and dynamics and the final integrated indicator of the efficiency of the industrial sector of the economy using the method of k-average.

3. Results

The developed methodology was implemented on the example of an industry in Polish regions. In particular, the results of the calculation of the industrialisation of the economy showed that industrial production in Poland was mainly concentrated in traditional industrial regions. In 2019, four voivodships, namely, Lower Silesia, Mazovia, Silesia and Greater Poland, were responsible for 56.6 % of sold industrial products (Table 2). In 2018, these voivodships also accounted for 52.8 % of the industry's GVA.

Mazovia, Silesia and Greater Poland also dominate in terms of innovation: in 2018, they accounted for a total of 56.5 % of net income from the sale of innovative products. At the same time, expenditures on innovative activities of industrial enterprises in these voivodships amounted to 40.4 % of the total in Poland. Also, during 2009–2018, the costs of innovative activities of industrial enterprises increased significantly in Lódz, Lesser Poland and Subcarpathia.

The implementation results of the second stage of the methodology (efficiency assessment of the industrial sector of Poland and its regions) revealed a relatively high level of current innovation activity in Lesser Poland and Subcarpathia, as well as the significant dynamics in the share of the net income from sales of innovative products in the net income from sales of industrial enterprises in general in Lódz (Table 3).

In Lódz, Lesser Poland and Subcarpathia, the indices of labour productivity (the volume of indus-

Tab. 2. Regional structure of the Polish industry and innovation, %

Indicator / Region	Level of industrialisation						Innovation					
	Realised industrial products			Industry's GVA			Expenditures on innovative activities of industrial enterprises			Net income from the sales of innovative products		
	2009	2019	increase	2007	2017	increase	2008	2018	increase	2008	2018	increase
Poland	100.0	100.0	x	100.0	100.0	x	100	100	x	100.0	100.0	x
Lower Silesia	9.1	8.8	-0.3	11.0	10.3	-0.7	7.3	5.2	-2.1	5.7	5.2	-0.5
Kuyavia-Pomerania	4.4	4.2	-0.2	4.8	4.7	-0.2	7.4	2.6	-4.8	4.4	2.5	-1.9
Lublin	2.3	2.6	0.3	3.1	3.1	0.0	3.3	3.2	-0.2	1.6	1.0	-0.7
Lubusz	2.5	2.5	0.1	2.8	2.8	0.0	1.4	1.9	0.4	2.1	3.0	0.9
Lódz	5.3	5.5	0.2	6.8	6.8	0.1	9.7	15.0	5.3	2.8	4.1	1.3
Lesser Poland	5.8	7.2	1.4	7.2	6.9	-0.3	5.2	10.0	4.8	7.0	8.6	1.6
Mazovia	20.6	20.1	-0.5	13.6	15.1	1.5	20.7	16.8	-3.9	26.4	28.6	2.2
Opole	2.3	2.2	-0.1	2.7	2.4	-0.3	1.2	2.3	1.1	1.4	1.6	0.2
Subcarpathia	3.0	3.5	0.5	4.1	4.6	0.4	4.0	8.2	4.3	3.1	2.8	-0.4
Podlaskia	1.8	2.0	0.2	1.9	1.9	0.0	1.8	1.0	-0.8	1.3	1.1	-0.1
Pomerania	5.9	6.4	0.5	5.7	5.9	0.2	9.2	5.3	-3.9	15.3	7.4	-7.9
Silesia	18.7	15.7	-3.0	17.4	16.4	-1.0	17.5	14.1	-3.3	15.8	15.3	-0.5
Swietokrzyskie	2.2	2.0	-0.1	2.8	2.3	-0.5	1.8	1.3	-0.5	1.7	0.8	-0.9
Warmia-Masuria	2.3	2.4	0.1	2.7	2.7	0.0	1.3	1.3	0.1	2.0	2.1	0.1
Greater Poland	11.0	12.0	1.0	10.3	11.0	0.7	6.5	9.5	2.9	6.9	12.6	5.7
West Pomerania	2.8	2.8	0.0	3.1	3.2	0.1	1.6	2.3	0.7	1.4	0.8	-0.6

Source: elaborated by the authors based on CSOP (2020).

trial output per employee) and gross average monthly wages exceeded the average values of these indicators in Poland. However, the gross monthly average wage of workers in these voivodships was lower than the average in Poland. The highest values of this indicator were maintained in traditionally industrial regions, i.e., Lower Silesia, Mazovia and Silesia. These three voivodships were also characterised by a high level of return on assets, and, in particular for Mazovia and Lower Silesia, the high level of profitability in general. In terms of dynamics, the industry also showed the highest profitability in Lesser Poland and Subcarpathia (Table 4).

Mazovia is the leader in the ranking of Polish regions in terms of the values of the overall integrated indicator of industrial functioning despite the decline in investment activity of its industry (Table 5). The industrial structure of this voivodeship is dominated by food production (19.9 %) and the production and supply of electricity, gas, steam and hot water (17.2 %). The share of innovative products in sales of the food industry was 18.3 % and 0.9 % in the production and supply of electricity, gas, steam and hot water. At the same time, in the structure of the industry, Mazovia had small shares of production with a significantly higher level of product innovation. The production of electrical equipment and paper and printing products (with the share of innovative products in sales amounting to 35.2 % and 32.7 %, respectively) occupied only 5.2 % and 1.2 % in the structure of sold industrial products of the voivodship. Thus, the industrial sector of the economy of Mazovia, which produces more than 20 % of Poland's industrial output, is the leader in the value of the overall integrated indicator and the integrated indicator of the current state by a wide margin but not the dynamics.

Instead, the highest dynamics of industrial functioning indicators is demonstrated by Subcarpathia, which occupies the third position in the ranking by the values of the general integrated indicator. It should be noted that the innovative activity of the industrial sector of this voivodship (both in terms of the current status and dynamics) significantly exceeded the average level of Poland. This is due to the high values of the share of innovative products that are new to the market and new to the export market. In addition, the index of innovation spending per employee was the highest in Poland.

The industry structure of Subcarpathia is highly diversified. It has four sectors (production of rubber and plastic products; production of metal products; production of cars, trailers and semi-trailers; production of other transport equipment) occupying 10–12 % each, and three (food production, production of products from wood, cork, straw, production of machines and devices) with more than 7 % each. At the same time, the level of innovation of these industries is in the range of 15 to 21 %.

Subcarpathia (as opposed to Mazovia) does not belong to traditional industrial regions as its share in the volume of sold industrial products of the Polish industry only amounts to 3.5 %, and the values of current indicators of labour productivity and capital investment are very low. However, over the past ten years, the industry of this region has significantly increased the level of product innovation, the profitability of turnover and assets, and the cost of innovation per employee. This gives grounds to suggest that should Subcarpathia continue with such positive trends, it has the prospect of becoming one of the new Polish innovation and industry centres.

In general, all regions of Poland can be divided into three groups by type of industry:

- the first group contains traditionally industrial voivodships with a high level of the industrial economy but also exhibiting signs of reduced potential, the need to diversify and optimise the structure of the industry, primarily based on increasing product innovation (Mazovia, Lower Silesia, Silesia, Greater Poland, Lesser Poland, Lódz, Pomerania);
- the second group accommodates voivodships with a low share in the national industry and characterised by medium or low values of partial indicators for the current state of labour activity, but high values of indicators for innovation activity and having the most indicators of dynamics (Subcarpathia, Podlaskia, Opole, Lublin, Lubusz); and
- the third group includes voivodships characterised by a non-industrial type of economy and mostly low values of industrial activity (Warmia-Masuria, Swietokrzyskie, West Pomerania, Kuyavia-Pomerania).

Despite growing investments in the industrial sector of the Polish economy, the decline is observed in labour, innovation and profitability of Polish industrial enterprises. This is confirmed by lower values of dynamics indicators compared to indicators of the current state and too innovative activity (0.36 vs 0.53). Therefore, the conducted analytical studies led to a conclusion that the greatest issue of the Polish industry is low innovation activity, which is among the lowest in the EU.

Tab. 3. Actual values of industrial functioning indicators of Poland and its regions*

Region	Investment activity						Labour activity						Innovation activity						The profitability of activity					
	Capital investment per employee, thousand PLN	Capital investment index per employee	Cost of capital investment per employee, thousand PLN	Capital investment value index per employee	Expenditure on innovation activities per employee, thousand PLN	Index of costs for innovation activities per employee	GVA labour per employee in the industry	GVA index per employee in the industry	Volume of sold industrial products per employee, thousand PLN	Index of sales of industrial products per employee	Gross monthly average salary of an employee, thousand PLN	Index of the gross monthly average wage of an employee	Share of the net income from sales of innovative products in net income from sales of industrial	Index of the share of net income from sales of innovative products in net income from sales of industrial	Share of net income from sales of innovative products for the market in net income from sales of industrial	Index of the share of net income from sales of products innovative for the market in net income from sales of	Share of net income from sales of products innovative for the export market in net income from sales of	Index of the share of net income from the sale of innovative products for the export market in the net	Return on assets, %	Return on assets index	Profitability of wages per employee, %	Index of profitability of wages per employee	Profitability of turnover (net), %	Profitability index of turnover
Poland	**28.57**	**1.31**	**104.2**	**1.39**	**8.0**	**0.94**	**151.1**	**1.74**	**523.44**	**1.65**	**4.68**	**1.58**	**9.1**	**0.73**	**3.2**	**0.49**	**1.7**	**0.63**	**4.9**	**1.48**	**33.14**	**1.43**	**4.7**	**1.42**
Lower Silesia	34.17	1.55	122.0	1.65	5.2	0.71	180.5	1.56	547.38	1.73	5.26	1.63	7.2	0.68	3.2	0.45	1.7	0.35	5.7	2.92	25.48	1.78	5.2	2.67
Kuyavia-Pomerania	16.18	0.82	82.9	1.23	4.2	0.34	129.2	1.70	438.79	1.61	4.03	1.59	6.3	0.42	2.3	0.50	0.5	0.47	7.8	3.35	32.54	1.62	6.0	2.59
Lublin	35.99	2.06	106.3	1.33	6.9	0.80	131.2	1.78	369.97	1.50	4.32	1.63	4.9	0.79	2.1	0.52	0.8	0.98	4.7	0.78	38.58	1.04	5.5	0.91
Lubusz	18.67	1.23	82.2	1.42	5.7	1.21	147.1	1.71	493.86	1.98	4.32	1.72	12.8	0.83	1.6	0.18	0.7	0.47	6.2	2.32	24.12	1.52	4.1	1.53
Lódz	43.66	1.69	87.0	1.21	18.4	1.58	142.1	1.88	452.40	1.93	4.41	1.75	9.2	1.15	1.8	0.55	0.5	0.48	3.8	0.87	27.25	1.22	4.1	0.94
Lesser Poland	30.08	1.51	104.0	1.33	10.8	1.72	137.3	1.59	480.23	1.70	4.43	1.58	12.1	0.87	4.7	0.48	2.3	0.42	6.0	1.32	40.44	1.39	6.1	1.33
Mazovia	39.78	1.30	165.7	1.32	9.6	0.71	206.0	2.04	752.43	1.54	5.20	1.54	10.3	0.77	3.2	0.67	1.9	0.74	5.9	2.88	42.45	2.10	5.5	2.67
Opole	18.31	1.18	113.3	1.97	8.4	1.96	146.2	1.55	491.78	1.47	4.38	1.56	8.0	0.94	5.2	0.90	3.4	1.57	4.8	0.48	29.21	1.15	3.7	0.88
Subcarpathia	22.57	1.45	96.6	1.75	13.6	1.99	126.6	1.86	355.35	1.69	4.08	1.63	9.0	0.67	4.7	0.88	2.4	0.80	5.1	3.33	27.25	1.27	4.2	2.76
Podlaskia	25.90	1.35	133.5	1.60	4.1	0.53	132.2	1.68	491.68	1.82	4.07	1.59	6.5	0.76	2.9	0.54	1.3	2.36	4.8	3.82	24.36	1.37	3.4	2.73

Pomerania	22.00	0.94	118.4	1.43	7.5	0.56	150.7	1.77	604.47	1.71	4.63	1.54	9.8	0.35	4.8	0.19	3.1	0.53	7.1	3.24	48.25	1.37	5.3	2.40
Silesia	28.75	1.27	72.6	1.30	7.1	0.80	156.9	1.70	531.73	1.52	5.28	1.47	8.8	0.76	3.0	0.58	1.8	0.79	5.7	1.98	27.46	0.86	2.7	0.93
Swietokrzyskie	15.29	0.47	79.2	1.08	4.2	0.71	131.8	1.55	432.21	1.44	4.10	1.53	4.5	0.49	2.7	0.55	0.9	0.75	5.3	0.58	45.21	0.85	4.3	0.47
Warmia-Masuria	17.70	1.50	102.0	1.55	3.3	0.96	119.3	1.72	390.13	1.74	3.88	1.63	8.9	0.67	1.9	0.58	0.9	0.77	5.2	3.93	27.36	1.14	3.7	2.80
Greater Poland	23.20	1.33	77.9	1.31	6.2	1.29	137.8	1.75	504.97	1.77	4.49	1.64	10.0	1.20	3.2	0.73	1.1	0.56	5.8	1.58	33.62	1.34	4.5	1.24
West Pomerania	20.67	1.20	114.6	1.31	5.3	1.38	131.9	1.80	429.27	1.60	4.32	1.62	3.2	0.37	0.9	0.28	0.4	0.22	4.9	4.44	26.78	1.12	4.1	3.73

*All indices were calculated as the ratio of 2018 to 2008.

Source: elaborated by the authors based on CSOP (2020).

Again, the analytical research has led to the conclusion that the big issue of the Polish industry is low innovation activity, which is among the lowest in the EU. Thus, the Polish industry, in terms of the share of the net income from the sale of innovative products in the net income from the sale of industrial enterprises in general, is significantly inferior to the German (Fig. 1).

At the same time, there is an average correlation between the values of this indicator in these countries (the correlation coefficient of 0.63). This can be explained by the integration of individual links in the global value chain as well as the action of the same factors influencing the development of the industrial sector of the economy of Poland and Germany.

This study focused on innovation activity because, under modern conditions for industrialised countries, industrial innovation is one of the decisive factors in ensuring the economic and social efficiency of the economy. Thus, studies (ZEW, 2020) have shown that product innovation significantly affects the performance of the industry. In particular, the surveyed German industrialists believed that improving product quality by increasing its innovation to 2.4 % increased sales and reduces production costs to 3.7 %.

On the other hand, a systematic review of research on innovation presented by Bierut (2016, pp. 79–82) suggested that increasing innovation increased labour market rotation. In some small and medium-sized firms, it could have led to lower employment through the release of "old" products, while in new and large firms, it could have become a factor in new job creation. As noted, "innovation is a source of rising wage inequality"; therefore, workers with the highest level of qualifications may see a rise in wages, and those with the lowest qualifications (doing routine work) may experience a decrease in the remuneration. The issue related to the impact made by product innovation on wages and employment in the industry is especially relevant in the era of the spread of Industry 4.0 and the growth of labour migration in Europe. Thus, there is a pressing need to determine the impact of innovation on key socio-economic indicators of the Polish industry, especially considering the fears that the growth of industrial product innovation will cause two very serious social problems: lower wages and lower employment in the industry. This study puts forward two scientific hypotheses.

The first hypothesis states that the growth of innovation activity contributes to increased employ-

Tab. 4. Taxonomic indicators of the industry's functioning in Poland and its regions

Region	Investment activity			Labour activity			Innovation activity			Profitability of activity			Integral indicator		
	Indicator of the current state	Indicator of dynamics	Overall figure	Indicator of the current state	Indicator of dynamics	Overall figure	Indicator of the current state	Indicator of dynamics	Overall figure	Indicator of the current state	Indicator of dynamics	Overall figure	Indicator of the current state	Indicator of dynamics	Overall figure
Poland	**0.37**	**0.41**	**0.39**	**0.45**	**0.39**	**0.42**	**0.53**	**0.36**	**0.44**	**0.42**	**0.34**	**0.38**	**0.44**	**0.37**	**0.41**
Lower Silesia	0.44	0.51	0.48	0.73	0.37	0.55	0.46	0.28	0.37	0.42	0.68	0.55	0.50	0.44	0.48
Kuyavia-Pomerania	0.07	0.13	0.10	0.14	0.35	0.25	0.23	0.21	0.22	0.77	0.67	0.72	0.20	0.28	0.25
Lublin	0.44	0.52	0.48	0.16	0.38	0.27	0.20	0.45	0.32	0.55	0.12	0.34	0.30	0.32	0.34
Lubusz	0.13	0.46	0.29	0.33	0.74	0.54	0.42	0.22	0.32	0.34	0.44	0.39	0.28	0.43	0.38
Lódz	0.72	0.55	0.64	0.30	0.86	0.58	0.29	0.52	0.41	0.18	0.18	0.18	0.33	0.46	0.41
Lesser Poland	0.45	0.59	0.52	0.31	0.32	0.31	0.81	0.37	0.59	0.75	0.31	0.53	0.54	0.38	0.47
Mazovia	0.76	0.34	0.55	0.98	0.48	0.73	0.59	0.47	0.53	0.70	0.76	0.73	0.75	0.49	0.63
Opole	0.29	0.81	0.55	0.34	0.12	0.23	0.83	0.77	0.80	0.26	0.12	0.19	0.38	0.31	0.37
Subcarpathia	0.40	0.79	0.59	0.08	0.55	0.31	0.72	0.54	0.63	0.30	0.59	0.44	0.28	0.61	0.48
Podlaskia	0.36	0.42	0.39	0.21	0.46	0.33	0.37	0.66	0.52	0.16	0.65	0.40	0.26	0.54	0.41
Pomerania	0.34	0.27	0.30	0.51	0.40	0.45	0.83	0.06	0.44	0.87	0.57	0.72	0.59	0.24	0.46
Silesia	0.24	0.34	0.29	0.63	0.15	0.39	0.51	0.43	0.47	0.21	0.18	0.19	0.36	0.25	0.32
Swietokrzyskie	0.04	0.08	0.06	0.16	0.07	0.12	0.24	0.31	0.27	0.58	0.01	0.29	0.18	0.06	0.15
Warmia-Masuria	0.13	0.52	0.32	0.03	0.49	0.26	0.33	0.39	0.36	0.26	0.61	0.44	0.14	0.49	0.34
Greater Poland	0.18	0.46	0.32	0.34	0.53	0.44	0.49	0.64	0.57	0.47	0.30	0.39	0.34	0.47	0.42
West Pomerania	0.26	0.45	0.35	0.22	0.44	0.33	0.00	0.06	0.03	0.27	0.74	0.50	0.00	0.30	0.20

Source: elaborated by the authors based on CSOP (2020).

Tab. 5. Ranking of Polish regions according to the values of integrated indicators of industrial functioning

№	Generalised indicator		Partial indicator of the actual situation		Partial indicator of dynamics	
1	Mazovia	0.63	Mazovia	0.75	Subcarpathia	0.61
2	Lower Silesia	0.48	Pomerania	0.59	Podlaskia	0.54
3	Subcarpathia	0.48	Lesser Poland	0.54	Warmia-Masuria	0.49
4	Lesser Poland	0.47	Lower Silesia	0.50	Mazovia	0.49
5	Pomerania	0.46	**Poland**	**0.44**	Greater Poland	0.47
6	Greater Poland	0.42	Opole	0.38	Lódz	0.46
7	**Poland**	**0.41**	Silesia	0.36	Lower Silesia	0.44
8	Lódz	0.41	Greater Poland	0.34	Lubusz	0.43
9	Podlaskia	0.41	Lódz	0.33	Lesser Poland	0.38
10	Lubusz	0.38	Lublin	0.30	**Poland**	**0.37**
11	Opole	0.37	Subcarpathia	0.28	Lublin	0.32
12	Lublin	0.34	Lubusz	0.28	Opole	0.31
13	Warmia-Masuria	0.34	Podlaskia	0.26	West Pomerania	0.30
14	Silesia	0.32	Kuyavia-Pomerania	0.20	Kuyavia-Pomerania	0.28
15	Kuyavia-Pomerania	0.25	Swietokrzyskie	0.18	Silesia	0.25
16	West Pomerania	0.20	Warmia-Masuria	0.14	Pomerania	0.24
17	Swietokrzyskie	0.15	West Pomerania	0.00	Swietokrzyskie	0.06

Source: elaborated by the authors based on CSOP (2020).

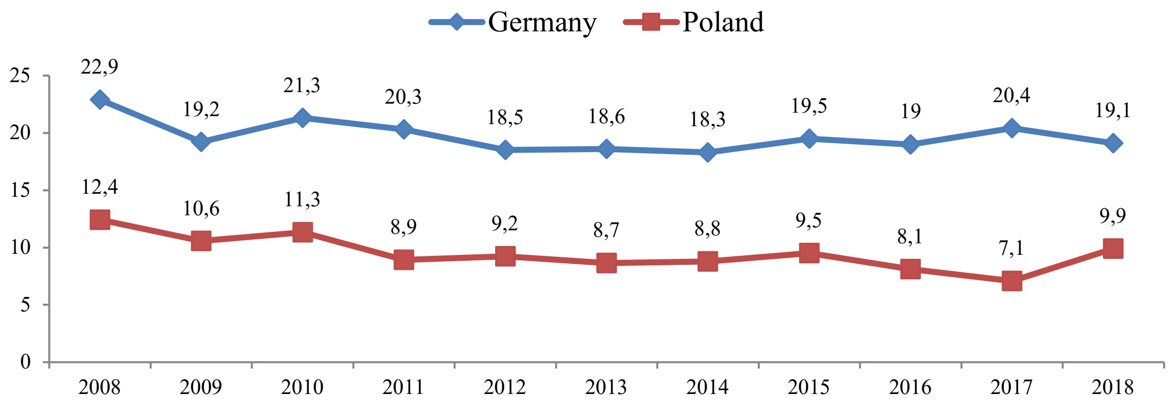

Fig. 1. Share of the net income from sales of innovative products in the net income from sales of industrial enterprises in Poland and Germany, %
Source: elaborated by the authors based on ZEW (2020).

ment in the industry. Theoretically, this hypothesis is substantiated by the fact that the introduction of innovations is accompanied by an increase in the level of manufacturability, automation of production processes, and, thus, the speed and quality of manufactured products, improving the organisation of labour. This, in turn, allows to significantly expand the range of industrial products and, thus, provides the emergence of new industries in related sectors of industry and economy and contributes to the expansion and strengthening of intersectoral ties. As a result, these processes will require new skills. New specialities will help create new jobs and boost employment.

An additional theoretical substantiation of this hypothesis is the results of Polish research by Piłka (2019, p. 28) regarding the impact of innovations on the development of the automobile industry. The research states: "The innovations introduced in the enterprise contribute to the increase and acceleration of production and employment growth". Also, Karpińska (2018, p. 227) used the examples of Podlaskia to substantiate that "...the influence of innovation on employment is connected to so-called creative destruction, which means that on the one hand innovation destroys existing working positions, but on the other hand it creates new ones — more specialised and requiring new knowledge". On the basis of surveys of enterprises in Podlaskia, Karpińska and Protasiewicz (2019) found that innovations demand had a positive effect on employment. In addition, 60 % of respondents argued that innovation promoted employment.

Analytical substantiation of the proposed hypothesis was performed using a correlation-regression analysis. Calculated on the basis of actual CSO data for 2008–2018, the correlation coefficient between the level of product innovation (in this study, assumed as the share of the net income from sales of innovative products in the net sales revenue of industrial enterprises in general) and employment in the industry (in this study, assumed as the share of the industry in the average employment of the economy) showed high interdependence (r=0.78) between these variables in Poland (Table 6). There is a direct linear relationship between the selected indicators.

To calculate the impact of product innovation on employment in the Polish industry, a linear regression equation is constructed:
Equation (2), based on its statistical characteristics, has a very high significance (Fig. 2). The interpretation of this equation, according to the actual data, confirmed its ability to predict employment in the Polish industry with an accuracy of 99.2 %.

Using the interpretation of the linear regression equation (2), it is determined that with increasing

$$Y= 0.27423x+25.11183 \quad (2)$$

where:
Y- the share of the industry in the average employment of the Polish economy (employment in the industry);
x - the share of the net income from the sale of innovative products in the net income from the sale of Polish industrial enterprises in general (the level of product innovation).

level of innovation of industrial products (x) to 1 pp, the average employment in the Polish industry (Y) will increase to 0.71 pp. In 2018, the innovativeness of the Polish industry products was 9.9 %, and the average employment in the Polish industry was 27.39 %. If the innovation of industrial products is increased to 1 pp (up to 10.9 %), the employment rate with an accuracy of 99.2 % will amount to 28.10 %, which is an increase to 0.71 pp.

Thus, there is a high direct relationship between the values of the industry's share in average employment and the values of the share of the net income from sales of innovative products in the net income from sales of industrial enterprises in general (as evidenced by statistical substantiation using the example of the Polish industry and confirmed the hypothesis that increasing the level of product innovation contributes to increased employment in the industry).

The second hypothesis states that the growth of product innovation contributes to an increase in the gross monthly wages of industrial workers. The theoretical justification for this hypothesis is that for products with a low degree of innovation and processing raw materials, GVA does not provide high marginal revenue nor financial prerequisites for increasing wages. Instead, an increase in the level of product innovation contributes to an increase in its value, demand, gross margin and financial prerequisites for increasing the gross average wage of industrial workers.

The relationship between the change in the level of product innovation and the change in the gross average monthly salary of a Polish industrial worker is generally graphically close to a parabola (Fig. 3).

The high closeness of the relationship (r=0.76) was determined by the correlation coefficient based on CSOP (2020) data for 2008–2018 between the

Regression Summary for Dependent Variable: Var1 (Spreadsheet31) R= 0.75330945 RI= 0.56747513 Adjusted RI= 0.51941681 F(1.9)=11.808 p						
	b*	**Std.Err. - of b***	**b**	**Std.Err. - of b**	**t(9)**	**p-value**
Intercept			25.11183	0.766818	32.74809	0.000000
Var2	0.753309	0.219222	0.27423	0.079805	3.43628	0.007434

Fig. 2. Statistical characteristics of the linear one-factor regression equation of the impact made by the level of product innovation on average employment in the Polish industry
Source: elaborated by the authors based on CSOP (2020).

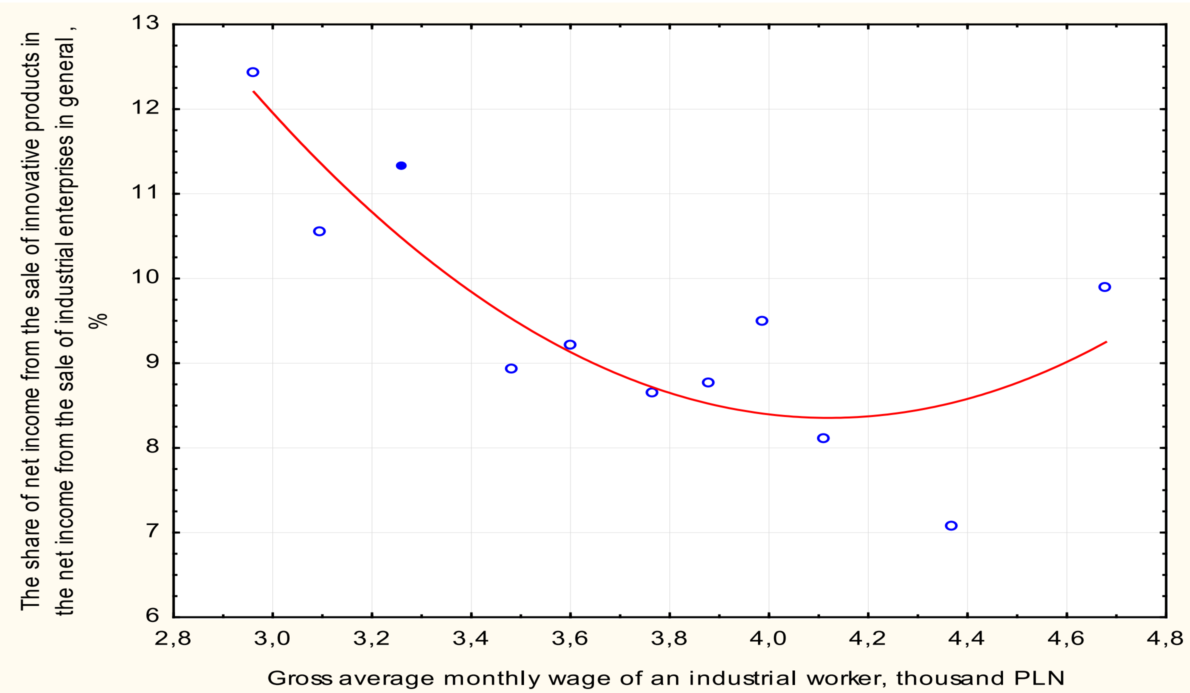

Fig. 3. Relationship between the share of the net income from the sale of innovative products in the net income from the sale of industrial enterprises in general and the gross average monthly wage of a Polish industrial worker
Source: elaborated by the authors based on CSOP (2020).

values of the index of gross average wages of industrial workers and the index of the share of the net income from sales of innovative products in the net sales revenue of industrial enterprises in general (Table 7).

The constructed quadratic equation of nonlinear regression (3) has a high significance, confirmed by its corresponding statistical characteristics (Fig. 4):

In equation (3), index values of indicators are used to achieve high forecasting accuracy, which could not be obtained when constructing a regression based on the actual data of the considered indicators.

Based on all actual data, the accuracy in the interpretation of this equation is ≈99.9 %, which allows high-precision forecasting of changes in the

$$M = -0.981666z + 0.480878z2 + 1.536449 \quad (3)$$

where:

M - the index of the gross average monthly wages of industrial workers in Poland;

z - the index of the share of the net income from sales of innovative products in the net income from sales of Polish industrial enterprises in general.

gross average monthly salary under the changing innovation level of the Polish industry.

The interpretation of the quadratic nonlinear regression equation (3) suggests that with the increase in the innovation of industrial products (z) to 1 pp, the gross average monthly wage of a Polish industrial

Tab. 6. Input data for calculating the linear regression equation of the impact of the level of product innovation on employment in the Polish industry, %

Year	Employment in the industry (the share of the industry in the average employment of the economy) (*Y*)	Level of product innovation (the share of the net income from sales of innovative products in the net sales revenue of industrial enterprises in general) (*x*)
2008	29.30	12.43
2009	27.90	10.56
2010	27.70	11.34
2011	27.70	8.93
2012	27.50	9.22
2013	27.50	8.65
2014	27.60	8.78
2015	27.50	9.50
2016	27.40	8.12
2017	27.40	7.08
2018	27.39	9.90

Source: elaborated by the authors based on CSOP (2020).

Tab. 7. Input data for the construction of a regression model of the impact of changes in the level of product innovation on the change in gross average monthly wages of the Polish industry

Year	Gross average monthly wage of an industrial worker, thousand PLN	Share of net income from sales of innovative products in the net income from sales of industrial enterprises in general, %	Index of gross average monthly wage of an industrial worker (*M*)	Index of the share of the net income from sales of innovative products in the net income from sales of industrial enterprises in general (*z*)
2008	2.96	12.43	x	x
2009	3.09	10.56	1.04	0.85
2010	3.26	11.34	1.05	1.07
2011	3.48	8.93	1.07	0.79
2012	3.60	9.22	1.03	1.03
2013	3.76	8.65	1.05	0.94
2014	3.88	8.78	1.03	1.02
2015	3.98	9.50	1.03	1.08
2016	4.11	8.12	1.03	0.85
2017	4.37	7.08	1.06	0.87
2018	4.68	9.90	1.07	1.29

Source: elaborated by the authors based on CSOP (2020).

Regression Summary for Dependent Variable: Var1 (Spreadsheet8) R= 0.72579317 RI= 0.52677573 Adjusted RI= 0.39156879 F(2.7)=3.8961 p						
	b*	**Std.Err. - of b***	**B**	**Std.Err. - of b**	**t(7)**	**p-value**
Intercept			1.536449	0.180922	8.49235	0.000062
Var2	-8.92948	3.242810	-0.981666	0.356500	-2.75362	0.028355
V22**	9.01979	3.242810	0.480878	0.172886	2.78147	0.027240

Fig. 4. Statistical characteristics of the quadratic, nonlinear equation of the impact made by product innovation changes on the change in gross average monthly wages of Polish industry workers

Source: elaborated by the authors based on CSOP (2020).

worker (M) will increase to 4 %. If the actual value of the level of innovation of Polish industry products (which in 2018 was 9.9 %) is increased to 1 pp (up to 10.9 %), the actual gross average monthly salary in the same year will increase to 190 (from PLN 4.68 thousand to 4.87 thousand) or 4 %. The accuracy of this predictive interdependence is very high (≈99.9 %), and the obtained result is significant.

Thus, there is every reason to believe that the hypothesis regarding the growth of product innovation contributing to an increase in gross monthly wages of industrial workers is theoretically, analytically and statistically confirmed and substantiated.

The irrational structure is the main reason for the generally low level of innovation in the Polish industry compared to other EU countries. To optimise the structure of the industrial sector of the economy by increasing the level of product innovation, i.e., achieving the desired share of sold innovative products in the industry in general, the authors developed an economic–mathematical model, the prototype of which is described in detail and tested in optimising the structure of the Polish industry (Ishchuk, Sozanskyy & Pukała, 2020). The optimisation model (4) is deterministic and reflects the presence of functional dependence, i.e., a change in the value of one indicator necessarily changes the value of another. The dependence exists between the dynamics in the share of individual industry segments in the structure of sold industrial products and the change in the share of innovative products in the volume of sold industrial products:

As already mentioned, the target function of optimisation is to increase the actual innovation value of industrial products to the desired level, and in this case, the share of innovative products in sales, which corresponds to the share of net sales of innovative products in the net sales of industrial enterprises.

When building the optimisation model (4), a set of criteria and constraints was formed:

$$\frac{I}{P} = \frac{I\left(\frac{I}{I}\right)\left(\left(\frac{I_q}{I}+\frac{I_m\left(\frac{I_m}{I_m}\right)\left(\frac{I_{m_1}}{I_m}+\frac{I_{m_2}}{I_m}+\ldots+\frac{I_{m_{23}}}{I_m}\right)}{I}+\frac{I_e}{I}+\frac{I_w}{I}\right)\right)}{P\left(\frac{P}{P}\right)\left(\left(\frac{P_q}{P}+\frac{P_m\left(\frac{P_m}{P_m}\right)\left(\frac{P_{m_1}}{P_m}+\frac{P_{m_2}}{P_m}+\ldots+\frac{P_{m_{23}}}{P_m}\right)}{P}+\frac{P_e}{P}+\frac{P_w}{P}\right)\right)} \rightarrow opt \quad (4)$$

where:

I - the innovative products of the industry;

P - the sold industrial products;

I_q - the innovative products of the extractive industry;

I_m - the innovative products of the processing industry;

$I_{m_1}.I_{m_2}.I_{m_{23}}$ - the innovative products of 23 manufacturing industries;

I_e - the innovative products for the supply of electricity, gas, stea and air conditioning;

I_w - the innovative water supply products; sewerage, waste management

P_q - the sold products of the extractive industry;

P_m - the sold products of the processing industry;

$P_{m_1}\ P_{m_2}\ P_{m_{23}}$ - the sold products of 23 manufacturing industries

P_e - the sold products for the supply of electricity, gas, steam, air conditioning, and water supply;

P_w - the sewerage, waste management.

1. The sum of shares of 4 segments of industrial activity in the structures of innovative products and sold industrial products is equal to 1;

2. The sum of the shares of 23 industries in the structures of innovative products and sold products of the processing industry is equal to 1;

3. The value of product innovation of 4 segments of industrial activity and 23 industries of the processing industry should grow. The shares should grow for those industries in which the actual value of product innovation exceeds the industry average in the structures of innovative products and sold industrial products.

The optimisation model (4) is solved by the method of linear programming. The target functional

Tab. 8. Optimisation of the Polish industry structure by the criterion of product innovation

Production	Factual data (2018)			Optimised data			Deviation of optimized data to actual		
	Structure of sold industrial products	Structure of innovative products	Share of innovative products in the volume of sales	Structure of sold industrial products	Structure of innovative products	Share of innovative products in the volume of sales	Structure of sold industrial products	Structure of innovative products	Share of innovative products in the volume of sales
Industry	**100.00**	**100.00**	**9.9**	**100.00**	**100.00**	**23.6**	**x**	**x**	**13.7**
Mining and quarrying	3.59	0.11	0.3	2.20	0.09	0.9	-1.4	0.0	0.6
Of which mining of coal and lignite	1.72	0.03	0.2	0.78	0.03	0.8	-0.9	0.0	0.6
Manufacturing	86.02	99.03	11.7	**87.40**	**99.20**	26.8	1.4	0.2	15.1
Manufacture of food products	14.04	7.62	5.5	9.20	7.70	19.7	-4.8	0.1	14.2
Manufacture of beverages	2.22	1.40	6.4	2.63	1.19	10.7	0.4	-0.2	4.3
Manufacture of tobacco products	0.74	0.55	7.5	0.98	0.45	10.9	0.2	-0.1	3.4
Manufacture of textiles	0.88	0.89	10.3	1.20	0.75	14.7	0.3	-0.1	4.4
Manufacture of wearing apparel	0.32	0.16	5.1	0.34	0.13	9.1	0.0	0.0	4.0
Manufacture of leather and related products	0.27	0.68	25.9	0.32	0.57	41.7	0.0	-0.1	15.8
Manufacture of products of wood, cork, straw and wicker	2.04	2.09	10.4	2.53	1.81	16.9	0.5	-0.3	6.5
Manufacture of paper and paper products	3.07	4.51	14.9	3.21	4.19	30.8	0.1	-0.3	15.9
Printing and reproduction of recorded media	0.84	0.70	8.4	0.85	0.58	16.0	0.0	-0.1	7.6
Manufacture of coke and refined petroleum products	6.97	10.03	14.6	4.87	4.02	19.5	-2.1	-6.0	4.9
Manufacture of chemicals and chemical products	4.54	3.45	7.7	5.40	3.11	13.6	0.9	-0.3	5.9
Manufacture of pharmaceutical products	0.81	0.78	9.8	1.00	0.65	15.3	0.2	-0.1	5.5
Manufacture of rubber and plastic products	6.26	4.08	6.6	6.51	3.74	13.6	0.3	-0.3	7.0
Manufacture of other non-metallic mineral products	3.91	2.04	5.3	3.95	1.77	10.5	0.0	-0.3	5.2
Manufacture of basic metals	4.31	1.70	4.0	4.35	1.46	7.9	0.0	-0.2	3.9
Manufacture of metal products	6.29	4.77	7.7	6.35	4.47	16.6	0.1	-0.3	8.9
Manufacture of computer, electronic and optical products	2.77	6.01	22.0	2.80	5.82	49.1	0.0	-0.2	27.1
Manufacture of electrical equipment	4.41	11.93	27.4	5.36	13.40	59.0	1.0	1.5	31.6
Manufacture of machinery and equipment n.e.c.	3.39	4.98	14.9	4.50	4.68	24.6	1.1	-0.3	9.7
Manufacture of motor vehicles, trailers and semi-trailers	11.24	22.51	20.3	13.20	31.54	56.4	2.0	9.0	36.1
Manufacture of other transport equipment	1.58	3.49	22.4	2.19	3.15	33.9	0.6	-0.3	11.5
Manufacture of furniture	2.79	1.87	6.8	2.80	1.61	13.6	0.0	-0.3	6.8
Other manufacturing	0.72	0.32	4.5	0.74	0.26	8.4	0.0	-0.1	3.9
Repair and installation of machinery and equipment	1.62	2.47	15.5	2.10	2.16	24.3	0.5	-0.3	8.8
Electricity, gas, steam and air conditioning supply	8.00	0.39	0.5	8.02	0.32	1.0	0.0	-0.1	0.5
Water supply, sewerage, waste management and remediation activities	2.38	0.47	2.0	2.39	0.39	3.8	0.0	-0.1	1.8

Source: elaborated by the authors based on CSOP (2020).

of optimising the industry structure is the level of product innovation, at which the gross average monthly wage of a Polish industrial worker will double and approach the average EU level. The numerical expression of the target functional is calculated using the interpretation of equation (2). It was established that for the gross average monthly wage in the Polish industry to double compared to the actual data of 2018 and amount to PLN 9.36 thousand (or about EUR 2.300), the level of innovation in industrial products should be 23.60 %, i.e., increase by 2.4 in times (from 9.9 % in 2018). Thus, the target functional of optimisation of the structure of the Polish industry (according to model (4)) is the achievement of product innovation at the level of 23.60 %.

According to the results of the calculation of model (4), considering the defined limitations, the optimised structure of sold products in general and innovative products, in particular, is obtained (Table 8).

According to the results, the Polish industry will be able to reach the level of product innovation of 23.60 % and increase the gross average monthly wage of workers if the structure of sales increases the share of production, for which the country has sufficient raw materials and innovation potential. These are, in particular, the production of the processing industry (textile, wood processing, furniture, and chemical) and certain types of mechanical engineering (highlighted in colour in Table 8).

In addition, the share of raw materials production with relatively low innovation potential, by definition, should decrease in the structure of the Polish industry. These are, in particular, manufactures of food products, coke and refined petroleum products, mining and quarrying, of which mining of coal and lignite. Such structural changes would increase the innovativeness of Polish industry products in general, and mainly, mechanical engineering products.

Conclusions

The theoretical contribution of the study is as follows. The approach to assessing the innovation of regional industries has been developed. Its peculiarity is the simultaneous analysis of direct indicators of product innovation and interrelated indicators that provide economic prerequisites for innovation and their economic results (indicators of investment activity, productivity, and profitability). In addition, the difference of this approach is in the use of the dynamics indicators (indices) together with current state indicators.

The theoretical assumptions of individual researchers regarding the relationship between innovation and wages and employment are mathematically substantiated and characterised.

An economic-mathematical model for optimising the structural parameters of industry according to the criterion of innovation has been developed and tested on the example of the Polish industry.

The results of the author's method of assessing the efficiency of the industrial sector at the macro and meso levels revealed signs of regional structural transformation of the Polish industry in the direction of forming potentially new industrial centres focused on increasing product innovation and productivity. In particular, a comprehensive assessment of investment, innovation and labour activity, as well as the profitability of the Polish industry, identified two key trends in the industrial development of voivodships: the gradual loss of industrial potential of classical industrial regions and, conversely, its increase in potentially new industrial regions.

The industrial sector of the economy of classical industrial regions is mainly characterised by high values of current indicators, but at the same time, low values of dynamics. This trend is most pronounced in the indicators of labour and innovation activity. On the other hand, other types of regions (those that increase industrial potential) are characterised by opposite features — relatively small values of actual indicators of industrial functioning, but high positive dynamics of these indicators and, especially, product innovation and productivity.

Further research has shown that one of the weaknesses of the Polish industry is low product innovation. The latter has a significant impact on the main economic and social indicators of this sector of the economy. The importance of innovation activity was confirmed by the results of correlation-regression analysis, which proved the adequacy of the hypothesis regarding the growth of product innovation contributing to increased employment in the Polish industry. The results of the interpretation of the constructed one-factor regression model proved the possibility of its application in forecasting employment in the Polish industry. Thus, it can be stated with high accuracy that the growth of product innovation to 1 pp will increase employment in the Polish industry to 0.71 pp.

The importance of innovation activity to ensure socio-economic development is confirmed by the second hypothesis that the growth of product innovation has a positive effect on the growth of gross average monthly wages. The developed quadratic nonlinear regression allows to highly accurately predict the change in the gross average monthly wage in the industry when the level of product innovation changes. The interpretation of this model allowed forming a statement that with the growth of product innovation to 1 pp, gross monthly wages in the Polish industry will increase to 4 %.

One of the basic conditions for increasing innovation activity is the structural transformation of the industry. To optimise the structure of the industrial sector of the Polish economy according to the criterion of increasing the level of product innovation, an economic and mathematical optimisation model was developed and solved using the method of linear programming. The target functionality of this model is the level of product innovation, at which the gross average monthly wage of Polish industry workers will double (to the EU average).

Further research will focus on modelling the impact of other factors, primarily labour productivity and investment (internal and external), on the level of innovation of industrial products.

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