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METHODS FOR RESEARCHING AND ASSESSING THE STATE AND GROWTH OF INNOVATION DETERMINANTS IN THE FIELD OF ADVANCED MANUFACTURING TECHNOLOGY

Key words

Innovation, monitoring, multidimensional assessment of innovation, advanced technologies.

Abstract

Intensive and uneven economic development of the world stimulates the undertaking of research and analysis aimed at identifying the state and the development directions of the innovation potential in different areas of the economy. This article describes a methodology of research in innovation supported by information technology, and in particular, the procedures for designating the key factors of growth promoting in innovation in the field of advanced and medium-advanced technologies. An application of this methodology makes it easier to see weak and strong points, and it indicates opportunities for improvement and development for the researched areas of the economy (industrial processing sectors, producer groups, and regions).

The developed methodology was applied in the research of selected sectors of industrial processing, producer groups, and of the economy at the regional level. Particular attention was given to providing the possibility of estimating the chances of product development belonging to the groups of advanced and

medium-advanced manufacturing technology and operation. The application of the methodology in the sector of highly advanced and medium-advanced technology of industrial processing is extremely important due to the need to address planned investments in the development of products with high innovative potential and promising commercial success, which in turn reduces the financial risk of the investment. The examples referred to in the article related to the use of the methodology of innovation studies have confirmed its usefulness and the possibility of further applications, such as in the planning of research and development of innovative products. The obtained results are of both strategic and operational importance, since they may be used for the formulation of the specialization of the Polish EU-28 production and determine the competitive position of Polish products in the industry. Moreover, research and innovation analyses provide relevant information that is useful to entrepreneurs in the creation of their development strategy, for example, in the decisions concerning the planning of the product volume by placing its own production in the competitive market of the industry.

Introduction

The purpose of this article is to present the changes in the results of the innovation evaluation of Polish industrial processing sectors, based on the example of comparative studies in 2009, 2011, and 2012, and, in particular, advanced technology branches of industrial processing whose products are appropriate for applications in Strategic Programme (PS), *Innovative Systems of Technical Support for Sustainable Development.*

The need for early detection of adverse trends in the economy in the area of innovation necessitates a multidimensional assessment with a view to developing appropriate mechanisms for the stimulation of the development of technology and the improvement of innovation.

Innovation is one of the many subjects (economics, marketing, finance, social statistics and economic analysis, organisation and management, insurance, regional analysis, and others) for which research must take into account the complexity of the phenomenon, and in its description – multi-dimensionality problems [1]. Moreover, innovation is one of the soft factors associated with the development of the creative category that produces new knowledge, related to the quality of infrastructure, including research and development and an effective (modern) industrial base [5].

The European Union comparative studies of sectoral innovation *Sectoral Innovation Watch* (SIW), used factors grouped in three thematic blocks (knowledge and technology, interactions between partners, and cooperation with institutions). In the assessment of *knowledge and technology,* the following indicators were used [2]:

- From the area outside the research and development activity[1]:
  - The intensity of raising funds from external sources,
  - The intensity of the investment into equipment and software;
- R&D intensity, which is the ratio of the expenditure on R&D activities to the value added or sold production;
- Participation of companies introducing new products to the market in agiven sector;
- Defining skills (HRST, the percentage of high-level, highly qualified managers, the proportion of highly skilled technicians, and the share of highly qualified specialists (ICT));
- Denoting the percentage of companies engaged in training activities.

Although the results of the work of the SIW are of particular importance for the determination of the technical distance within the European Union industry, they have been criticized by the authors from the Centre for European Economic Research (ZEW) [2] because of the use relative specialisation index in technology (RCA) [3]. One of the elements of the RCA was being questioned, namely, the productivity of a patent, which is the relationship between patent applications and the economic performance. It was considered that, in view of low patenting capabilities of many countries, patents could not be accepted as an element of European expertise assessment in technology.

The European studies carried out in 19 economic areas in the EU-27, Japan, and the United States, indicate that the European Union still focuses on the traditional industry (machinery, metal products), while the US and Japan focus mainly on industrial support technologies (biotechnology, nanotechnology and ICT).

The results presented in this article for a multidimensional evaluation of innovation pertain to a *selected area* of industry, including the production of chemicals and chemical products (NACE[2] 20: medium-high technology), metal products (NACE 25; medium-low), electronic and optical products (NACE 26; high), electrical equipment (NACE 27; medium-high), and machinery and equipment (NACE 28; medium-high). From the selected area of the industry, for the product analysis, products and services were selected that shared similar technical and functional characteristics to the planned and achieved results in PS [8–10].

1. A description of selected indicators for researched sectors

The researched sectors in the years 2009–2013 indicate that the importance of the selected Polish branches of industrial processing slightly decreased in the production of industrial processing sales (a decrease from 26.2% in 2009 to

[1] Non-R&D innovation activities.
[2] Polish enterprise classification number.

24.9% in 2013). Researched sectors, until 2012, showed an increase in the trend of production sales, with the exception electronic and optical equipment production where there had been a decline. The increase of production sales in 2013 occurred only in the production of electrical products (Fig. 1).

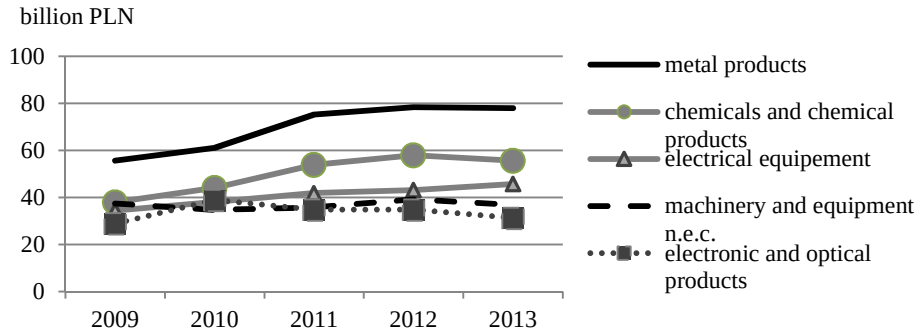

Fig. 1. Changes in the value of production sales in selected sectors of the industrial processing in the years 2009–2013 (elaboration based on GUS data – Central Statistical Office)[3].

The highest investment in innovation activities of the five researched sectors was made in *metal products manufacturing* (8.2% of the investments of industrial processing in 2013), and the lowest was in *electronic and optical equipment manufacturing* (2.7%) It should be noted that, in 2013, most of the surveyed sectored sustained significantly higher expenditures on R&D activities, per employee, than the average in industrial processing (Fig. 2).

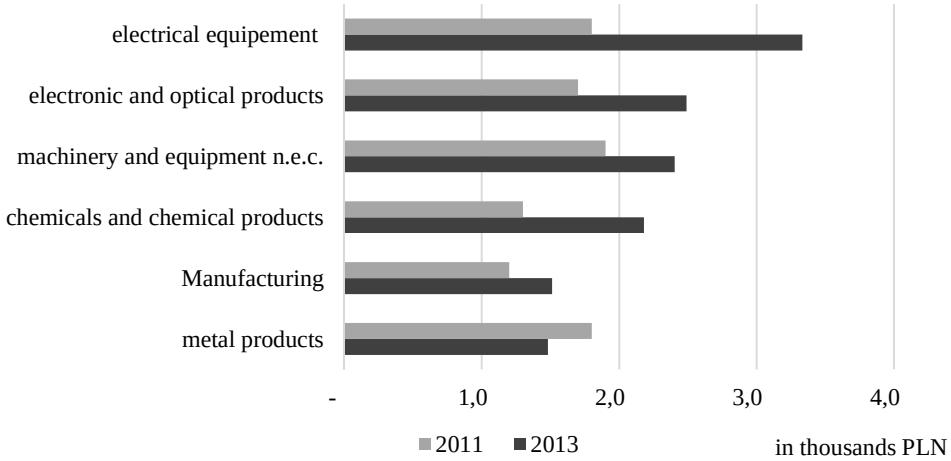

Fig. 2. The expenditure on R&D activities per one employee in the researched branches in comparison with the average in the processing industry in the years 2011–2013

[3] Also in the subsequent Tables, unless stated otherwise.

The presented issue, due to the importance of *selected sector* in modernising the economy, should meet with the interest of the companies from the researched sectors and constitute a contribution to sectoral analyses.

2. The methodology for multidimensional evaluation of innovation

To designate the synthetic evaluation of the innovation potential of industrial processing sectors, Regional National Summary Innovation Index (RNSII) was used, whose formula was included in the schema of the presented algorithmic model (Fig. 3).

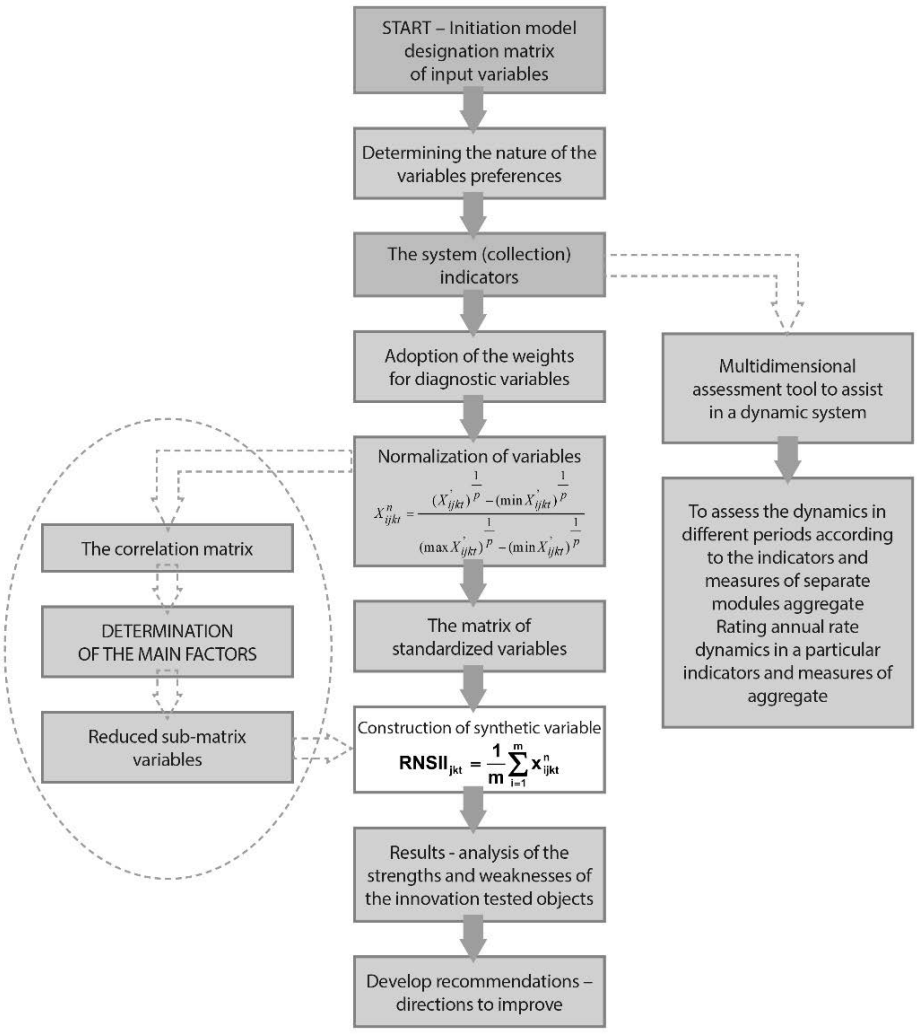

Fig. 3. The diagram of the algorithmic model for multidimensional comparative analysis of innovation [7].

The innovation of sectors in the *t* year is referred to as a matrix, X^t, which contains *n* groups (sectors) (*n* = 24), and *m*-dimensional (*m* = 19 factors). The design of the synthetic indicator of sector innovation was a model that aggregates the calculation of synthetic indicator [6].

An important aspect in the applied method of the multi-parameter evaluation of innovation in the selected sectors of the Polish industrial production is the matter of relativity, that is, the reference point of measurements. This reference point was the mean value for industrial processing.

In the assessment, the level of innovation in industrial processing sectors was established based on the following classification [11]:

I	Strong sector, when $d_j > \bar{d} + s$;	Medium-weak when $\bar{d} - s < d_{j \le \bar{d}}$;	III
II	Medium-strong when $\bar{d} < d_{j \le \bar{d}} + s$;	Weak (blank areas) when $d_j \le \bar{d} - s$	IV

where the measure of the development d_j corresponds to level of synthetic indicator of the sector innovation, and $\bar{d}$, *s*, respectively, mean the arithmetic mean and standard deviation of the studied factor.

Standardized factors for Polish sectors were reduced, and the modified matrix of indicators satisfying the condition of at least mean correlation was ordered. Indicators with the lowest correlation values were rejected. To carry out further assessments of innovation, a modified set of indicators was adopted which was presented during the discussion of surpluses and deficiencies of factors shaping innovation.

In the development of recommendations for decision support in the area of advanced technology, the procedure presented in Figure 4 was used.

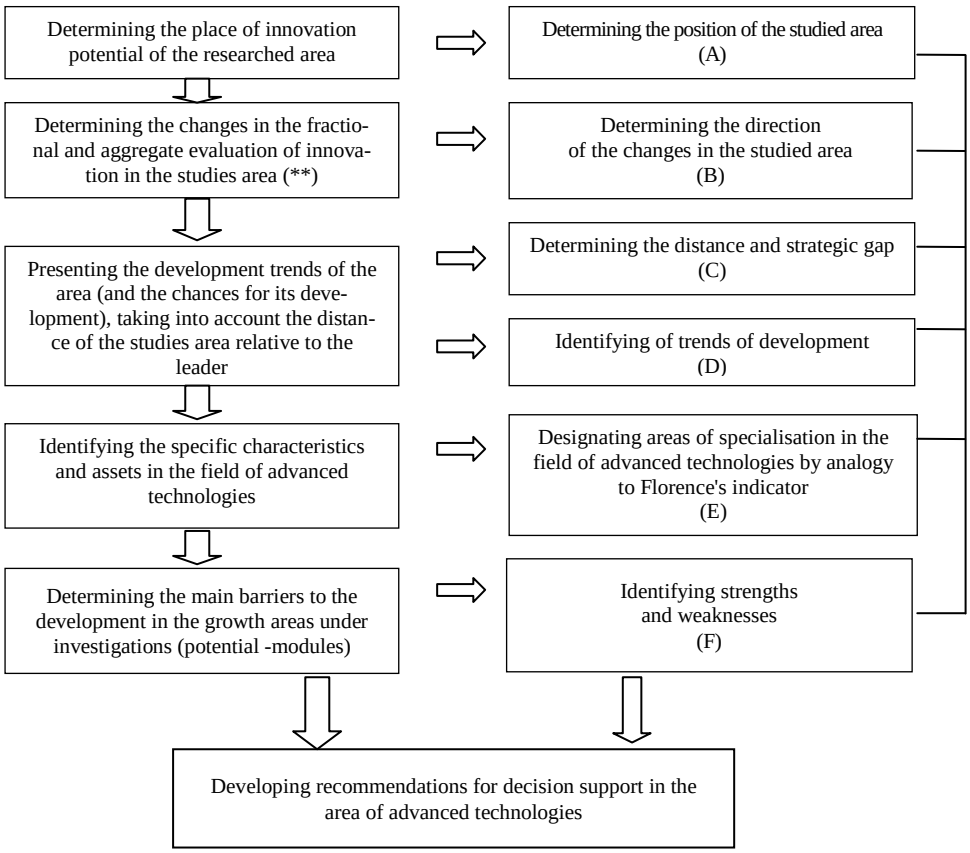

Fig. 4. The procedure for supporting decision-making process in the area of advanced technologies [4], [7].

Due to the limited scope of this article, only selected findings are presented.

3. The results of a multidimensional evaluation of innovation of selected sectors in industrial processing

The results of the conducted research, with an indication of the synthetic value of the innovative potential of sectors in 2009–2012, ranking sites and the obtained the level of innovation are shown in Table 1. Among the sectors accepted for research, the highest ranking (2nd place in 2012 with the synthetic innovation potential of 0.332) was received by electronic and optical equipment manufacturing.

Table 1. The level and the potential of innovation for industrial processing sectors in 2009, 2011, and 2012 (*order according to the results of 2012*)

Production sectors, taking into account the place in the ranking:	2009	2011	2012	Synthetic innovation potential (2012)
01. pharmaceutical products- *the leader*	I	I	I	0.427
02. electronic and optical equipment	I	I	I	0.332
08. metal products	II	II	II	0.253
12. electrical equipment	II	I	III	0.228
16. chemicals and chemical products	III	III	III	0.209
18. machinery and equipment	III	II	III	0.203

In the research, the impact of partial evaluation (modules) was studied on the synthetic evaluation of innovation for electronic and optical equipment manufacturing (Tab. 2).

Table 2. The impact of modules on the synthetic evaluation of innovation in electronic and optical equipment manufacturing in the years 2009 and 2011

Manufacturing of electronic and optical equipment (and computers)	Module share in %				
	Module I Work resources and the creation of new knowledge	Module II R&D Intensity	Module III innovation financing and non R&D	Module IV Modernity (**)	Module V Productivity of resources and energy
2009	18.6	1.0	3.0	36.8	40.5
2011	29.6	4.4	6.2	33.8	26.0
2012	21.7	1.3	4.5	40.4	32.2
Mean	23.3	2.2	4.6	37.0	32.9

The analysis of the data presented in Table 2 indicates that the synthetic assessment of the production innovation of electronic and optical devices was influenced the most by *modernisation* (37.0%), *the productivity of resources and energy* (33.9%) and *work resources*, and *the creation of new knowledge* (23.3%). At the same time, the share of other modules was very low, for example, *R&D intensity* (on average for the years 2009–2013 – 2.2%), and *innovation financing and non-R&D* (4.6%).

Assuming a uniform distribution of the importance of indicators (i.e., 5.26%, with 19 explanatory factors) each factor should have the same contribution to the development of innovation. However, in the production of electronic and optical devices, eight factors show higher impact, including two indicators from Module V, *Productivity of resources and energy (productivity of fixed assets and machinery, electricity consumption),* two factors from Module I (*human resources and the creation of new knowledge*, including *participation of*

staff in R&D activities and the participation of researchers and three related to the application of advanced technologies *(computers for the control and adjustment of automation processes, participation in investments, the computer-controlled production lines*). The remaining eleven factors show a much lower contribution (Fig. 5), which is particularly associated with very use of low innovative potential in the area of *innovation financing*, and a low level of training of human resources.

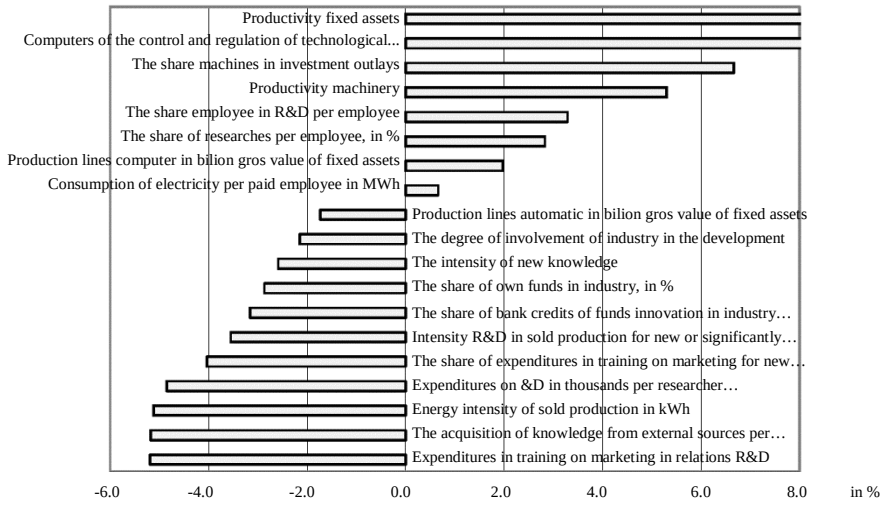

Fig. 5. Surpluses and shortages of factors shaping innovation in the production of electronic and optical equipment, taking into account an even distribution of the importance of factors (5.26%) (an average rating of 2009–2012)

In assessing innovation of selected industrial processing sectors, the condition has been maintained that the applied indicators are stimulants. In this case, the obtained negative aggregate deviations are the result of a deterioration in the comparable periods (t and t + 1). On the basis of the analysis, it can be concluded that, in the production of electronic and optical devices, the increase in synthetic impact deviation was positively influenced by the increase results of the following four modules: *work resources* and *creating new knowledge*, innovation *financing and non-R&D*, and *R&D intensity and modernisation*, while the results worsened in relation to the *productivity of resources and energy*.

The studies carried out in the Institute for Sustainable Technologies in Radom identified specific characteristics and assets in the field of advanced technologies. In the researched sectors, *the manufacture of machinery* and *metal products manufacturing* show a high rate of specialization in the field of machining centres, and the production of chemicals for automated and

computer-controlled lines. Moreover, the quantification of the contribution (share) was taken into account of the explanatory variables for the modernisation variable (application of advanced techniques). This quantification in the production of electronic and optical devices suggests that the *computers for controlling and regulating processes* (on average, 37.9%) have the greatest influence on the aggregate variable assessment of modernisation and their influence shows a rising trend. This factor, together with the participation of the *machines in the investment,* more than doubles the advantage (70.5%) over other factors (29.5%).

Conclusion

The verification of the methodology provided results lead to the conclusion that the best rating was obtained for the manufacture of electronic and optical equipment, which, in the 4-level rating, received Level I for innovation, and the weakest was the manufacture of machinery and technical equipment (Level III of innovation).

The results of the conducted assessments of innovation in *industrial processing* have allowed a formulation of specific recommendations. The identified recommendations point to the need to support the decision-making processes in the designated sectors, mainly in the following areas: low intensity of R&D activities (including the purchase of new knowledge and software) and innovation outside the R&D activities (investments in machinery, marketing, provision of a suitable environment for innovation).

The areas that require external support and direction are the intensity of innovation in areas outside the R&D activities (mainly through purchases of machinery, including imports) are primarily manufacturers of electrical equipment, machinery and equipment, and the manufacture of electronic and optical equipment.

These sectors are an opportunity for the R&D sector to strengthen them through the ready products (applications), which are the results of the Strategic Programme, development programmes, as well as by strengthening the research potential of these industries in joint solutions for new or upgraded products.

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Metodyka badania oceny stanu i uwarunkowań wzrostu innowacyjności w obszarze zaawansowanych technologii wytwarzania

Słowa kluczowe

Innowacyjność, monitoring, wielowymiarowa ocena innowacyjności, zaawansowane technologie.

Streszczenie

Intensywny i nierównomierny rozwój gospodarczy świata skłania do przeprowadzania badań i analiz, których celem jest identyfikacja stanu, kierunków i możliwości rozwoju potencjału innowacyjnego w różnych obszarach gospodarowania. W artykule przedstawiono metodykę badania innowacyjności wspomaganą przez aplikację informatyczną, w szczególności uwzględniono procedury wyznaczania kluczowych czynników stymulujących wzrost innowacyjności w sektorze zaawansowanych i średniozaawansowanych technologii. Zastosowanie metodyki ułatwia prace związane z wyznaczaniem słabych i mocnych stron, ze wskazaniem możliwości poprawy i szans rozwojowych badanych obszarów gospodarki (działów przetwórstwa przemysłowego, grup producenckich oraz regionów).

Opracowana metodyka znalazła zastosowanie w badaniach wybranych działów przetwórstwa przemysłowego, grup producenckich oraz gospodarki w układzie regionalnym. Szczególną uwagę zwrócono na zapewnienie możliwości szacowania szans rozwojowych produktów należących do grup zaawansowanych i średniozaawansowanych technologii wytwarzania i eksploatacji. Zastosowanie metodyki w sektorze wysokiej i średniowysokiej techniki przetwórstwa przemysłowego jest niezwykle istotne ze względu na zapewnienie adresowania planowanych inwestycji finansowych w rozwój produktów o wysokim potencjale innowacyjnym i rokujących szanse sukcesu komercyjnego, co z kolei pozwala na zmniejszenie ryzyka finansowego inwestycji. Wymienione w artykule przykłady zastosowania metodyki badania innowacyjności potwierdziły jej przydatność i możliwości kolejnych aplikacji, m.in. w planowaniu badań i rozwoju innowacyjnych produktów. Uzyskane wyniki mają znaczenie zarówno strategiczne, jak i operacyjne, służą bowiem do sformułowania specjalizacji polskiej produkcji w UE-28 czy też określenia pozycji konkurencyjnej polskich produktów w branży. Badania i analizy innowacyjności dostarczają także istotnych informacji przydatnych przedsiębiorcom w tworzeniu strategii rozwojowych, np. w decyzjach dotyczących planowania wolumenu produktów przedsiębiorstwa poprzez umiejscowienie własnej produkcji na konkurencyjnym rynku danej branży.