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A multivariate approach to the identification of initial smart specialisations of Polish voivodeships

JEL Classification: *R11; R12; O32; O38*

Keywords: *smart specialization; voivodeships (regions); synthetic measures; industry*

Abstract

Research background: The identification of smart specialisations should be based on information allowing the identification of resources and capital in the regions, which constitute the unique value of the area providing for the development of competitive advantages based on innovations and achievements in the research and development activities.
Purpose of the article: The key goal is to present the proposal to use an aggregate (synthetic) measure for the purpose of identifying regional development potentials and next the initial smart specialisations (RSS). This approach is particularly useful at the very initial stage of recognizing the potential in the region, and — after some modifications — may offer a useful tool for assembling the de-velopment of industries (services) in the region. The additional goals are: (1) to organize the knowledge regarding statistical approaches and selected methods to be used in the process of identifying initial smart specialisations in regions (RSS); (2) exemplification of the presented methodology for the initial regional smart specialisations (RSS) identification in voivodeships in Poland based on a multivariate approach.
Methods: Multivariate statistical analysis (MSA) methods are used in the identification procedure of initial regional smart specialisations (RSS), which allowed for performing the assessment in 4

areas: resources and capital; specialisation; development potential (dynamics); the involvement in research and development and innovative activities. They can also be extended with additional dimensions related to the cooperation of enterprises with social or environmental priorities.
Findings & Value added: The conducted procedure allowed identifying NACE rev. 2 divisions useful in determining development potentials in Polish regions and later the initial smart specialisations (RSS). The identified initial RSS for Polish voivodeships can be a starting point for building regional smart specialisations based on values supply chain or other premises. Due to the universal nature of the proposed methodology, it can be widely used at the level of subregions, regions and the EU countries.

Introduction

Foray is considered the creator of the smart specialisation concept, as a member of the specialist group known as "Knowledge for Growth" established to provide consultancy for the European Commission on the development of the Europe 2020 strategy (Capello, 2014). In Foray's opinion regions have the ability to discover new opportunities and to concentrate resources and competences in these newly found domains (Foray, 2014a), (Foray, 2014b).

As emphasized in the subject literature (Godlewska, 2013), although smart specialisation seems to be a new term, it actually combines the concepts being developed for years in the theory of regional development and international trade, such as:

– specialisation, the importance of which was already emphasized by the authors of the classical theory of international trade: Smith in the theory of absolute advantage (Smith, 1776) and Ricardo in the theory of comparative advantage (Ricardo, 1929);
– competitiveness, in economics, generally understood as the ability to succeed in economic competition (Kamerschen *et al.,* 1991). The foundations for the development of research addressing regional competitiveness were provided by, e.g., von Thunen's location theory (von Thünen, 2009; Sinclair, 1967), Marshall's theory of industrial districts (Marshall & Marshall, 1879; Marshall, 1919) and Porter's concept of clusters (Porter, 1990);
– knowledge and innovation. The concept of innovation in economic sciences was introduced in 1911 by Schumpeter (Schumpeter, 1911). Knowledge is the essence of the innovation process (Quintane *et al.,* 2011).

At the same time, it has to be based on the endogenous potential and competitive advantages inherent in a given region of economic, infrastructural, social and environmental nature. Endogenous factors represent the developmental force of a region resulting directly from its socio-economic potential, location, infrastructure, the availability of production factors, entrepreneurship and intra-regional policy, which allow the development of economic specialisations constituting the basis for the development of a strong competitive position. In turn, as part of the broadly understood EU policy, identifying, funding and developing smart specialisations should be accompanied by a broader outlook, also taking into account the priorities formulated at the level of the main EU development strategy, and among them the so-called difficult areas related to adverse demographic changes, environment pollution or climate change (Godlewska, 2013). The studies attempting to develop an evaluation methodology of the smart specialisation conceptual framework in the context of adherence to current European Cohesion Policy are particularly important (Gianelle *et al*., 2020).

Conceived within the reformed Cohesion Policy of the European Commission, smart specialisation is a place-based approach characterised by the identification of strategic areas for intervention, based on analysing both strengths and the potential of the economy and also on the Entrepreneurial Discovery Process (EDP) with wide stakeholder involvement. It is outward-looking and embraces a broad view of innovation including, but certainly not limited to, the technology-driven approaches, supported by effective monitoring mechanisms (Smart Specialisation Platform; s3platform.jrc.ec.europa.eu).

The key goal of the paper is to present the proposal to use an aggregate (synthetic) measure ($SMSS$) for the purpose of identifying regional development potentials and next the initial smart specialisations (RSS). This approach is particularly useful at the very initial stage of recognizing the potential in the region, and — after some modifications — may offer a useful tool for assembling the development of industries (services) in the region. The additional goals are: (1) to organize the knowledge regarding statistical approaches and selected methods to be used in the process of identifying initial smart specialisations in regions (RSS); (2) exemplification of the presented methodology for the initial regional smart specialisations (RSS) identification in voivodeships in Poland based on a multivariate approach.

Many of the available studies addressing smart specialisations are based on the evaluation using soft qualitative criteria and methods (Wojnicka-Sycz, 2020). The quantitative methods are only mentioned. This study emphasizes the presentation of methodology to be used in identifying smart specialisations or development potentials in countries or regions not only for the analysed region, but also others, allowing for the assessment of their competitive position.

The presented study is organized as follows. Section 1 offers an introduction into a theoretical approach to the identification of initial regional smart specialisations. The advantages and disadvantages of the selected multivariate statistical analysis (MSA) methods, useful in identifying the initial regional smart specialisations or evaluation process are briefly discussed. Section 2 describes the proposed procedure for identifying initial smart specialisations using synthetic measures (linear ordering methods), while Section 3 presents and interprets the empirical results. The study is concluded with a discussion and an outlook of the current research.

Literature review

The basic goals of smart specialisation listed in the subject literature are as follows (Foray & Goenaga, 2013; Bosch & Vonortas, 2019):

- facilitating the development and growth of new activities with the potential for innovation and spillover,
- generating new options for production and thus diversifying regional economic systems,
- establishing critical networks and clusters within a diversified system.

The concept of smart specialisation requires generating unique assets and opportunities corresponding to the industry and services structure and knowledge base specific to a given region. The assumptions of the smart specialisation concept impose the following tasks on the regions: to identify their own competitive advantages and understand the international and national context of industries and services to learn from others or collaborate with them (McCann & Ortega-Argilés, 2016; Bosch &Vonortas, 2019). The requirement of identifying smart specialisations is intended to support regions in prioritizing their research and innovation resources better in order to build critical mass in the areas of the existing comparative advantage. Smart specialisation is the result of the place-based development policy, as the opposite of one-size-fits-all policy, which prevailed in the past (Tripl *et al.,* 2019; Balland *et al.,* 2019). It should not be done in a top-down way, but emerge as a result of an entrepreneurial discovery process carried out by the entities with technical and market knowledge (Hausmann & Rodrik, 2003; Uyarra & Marzochii, 2018). Regions should identify smart, outward-oriented specialisations taking into account their competitive position on both national and international markets (Uyarra & Marzochii, 2018). At the same time, they should be developed in harmony with the local capabilities existing within each region (Santoalha, 2019). Smart specialisation also requires mobilizing regional stakeholders and resources around an excellence-driven vision of their future (Heimeriks & Balland, 2016; McCann & Ortega-Argilés, 2013; Sotarauta, 2018).

The identification of smart specialisations should combine the elements of the available regional resources' balance, attitudes of local entrepreneurs and decision makers and the expectations resulting from the current development policy objectives, in order to use various regional advantages by stimulating cooperation and expanding it beyond the regional and national borders.

In the light of regional strategic documents of Polish voivodeships, the process of identifying smart specialisation areas was generally carried out in accordance with the basic recommendations for preparing the strategy methodology included in the Guide of Research and Innovation Strategies for Smart Specialisation (RIS3) (EC, 2012). Due to the absence of limitations in the methods and research tools used to identify smart specialisations at regional level, the applied procedures vary across regions. The range of used methods can be divided into two groups:

– expert methods covering techniques and research aimed at collecting opinions, information, suggestions, declarations, plans or developing solutions, and among them heuristic methods, including focus methods, expert panels, debates and public consultations; preparing development scenarios; online discussion forums; focus group interviews (FGI); individual and in-depth interviews (IDI), as well as telephone ones (CATI);
– quantitative methods covering the application of measurement as well as statistical and econometric analysis based on the quantitative data processing.

The definite advantage of the first ones is obtaining detailed, specific information about the entities as well as the opinions presented by the broadly understood stakeholders. The strength of the quantitative approach is the universal measurement of the phenomenon providing the possibility for objective assessment and comparison of the resources and regions, and also the assessment of their position competitiveness and the critical mass identification.

In general, in Poland, smart specialisations were identified as a result of the conducted diagnosis of endogenous potentials (SWOT analysis) and the knowledge acquired using other qualitative, heuristic or survey methods (Pander *et al.*, 2014) as well as statistical methods (Gulc, 2015) . The advanced quantitative methods were used to a small extent. Among the methods applying statistical data, the most commonly used are the indicator analysis and location indicators. Econometric methods or shift share analysis are less frequently applied.

Data constitute the basis for using statistical methods. The simplest and most frequently used form of their analysis is the construction of indicators. The review of RSS documents binding in Poland in 2019 allowed collecting information about the commonly used indicators (Tab. 1). The indicators were grouped according to the basic areas taken into account when identifying smart specialisations. Regions identify smart specialisations searching for industries and sectors characterized by the advantages primarily in terms of the activity scale, innovation, competitiveness and social potential.

The examples of advanced quantitative methods, used in RSS analysis and identification, include productivity analysis (TFP — total factor productivity) (Pander *et al.*, 2014) or econometric models showing the link between local characteristics and the implementation of projects (Mieszkowski & Barbero, 2020). In turn, the classification and linear ordering methods were presented based on the example of the European Union regions by Navarro *et al.* (2014). In economic research, shift-share analyses were used to identify competitive and structural advantages in the sectors of high and medium-high technology industries and knowledge-based services in the EU countries and regions (Sobczak, 2012; Šipilova, 2015).

The quantitative methods, according to the authors, worth considering in the process of identifying and evaluating smart specialisations include: indicator analysis, location quotient (Florence's specialisation), shift share analyses and synthetic measures. Table 2 summarizes the advantages and disadvantages of the selected statistical methods, useful in identifying smart specialisations.

Methodology: proposal of a procedure identifying initial smart specialisations

This part of the article presents in detail the statistical approach to selecting initial smart specializations (RSS). The identification of regional potentials for the development of smart specialisations using linear ordering methods includes the following analysis stages:

1. Defining development potential, understood as the key characteristics of the resources and capital deciding about the possibilities of developing and constructing a competitive position within the framework of the selected economic activity.
2. Identifying key factors (areas) underlying the definition of smart specialisations in regions (voivodeships).

3. Selecting indicators and statistical measures allowing the description of development potentials in accordance with the selected key factors.
4. Selecting linear ordering methods (for the development of a synthetic measure of smart specialisation, *SMSS*).
5. Analysis and interpretation of the findings.

An important step in RSS identification is to define the areas representing sources of competitive advantage development, constituting the development potential. They include the resources available in the region, forming the basis for further development (B *BASE*) and the current trends observed in a given industry (service), manifested by an increase or decrease (D *DYNAMICS*). The positive trends observed so far within a given industry may represent an important indication regarding the industry maturity and readiness for further development. The assessment of the competitive position presented by a given industry, expressed by the level of specialisation (S *SPECIALISATION*) offers yet another potential worth considering in the carried out analysis. The relatively high importance of a given industry, compared against other territorial units, indicates a certain advantage in the form of specialisation, which may become the basis for further development. It should, however, be highlighted that it is not a necessary or sufficient condition. In the case of transmission/service industries and specialisations, new for the emerging sectors, the low level of specialisation can be compensated by other development potentials, such as a sufficient base, high growth dynamics and involvement in innovation activities. Moreover, the necessary condition for RSS development is the industry (services) openness towards creating and/or implementing innovations (I *INNOVATION/RESEARCH AND DEVELOPMENT*).

The aforementioned four potentials (base B, dynamics D, specialisation S and innovation I) allow assessing the resources available in a region, important for its competitive position development based on RSS. In addition — taking into account the possibility of funding RSS from public funds — these four potentials can be expanded by another two, namely (1) *INVOLVEMENT*, illustrating the tendency of enterprises to cooperate and achieve goals within the framework of projects and grants, and (2) *PRIORITIES* emphasizing factors crucial for the development of regions as a whole, taking into consideration social, environmental or other desirable development directions. Social priorities can be manifested by the promotion of solutions (industries) facilitating the improvement of working conditions, or reducing income disparities and poverty. Environmental priorities may be focused on funding the development of industries using or creating environmentally friendly standards and eco-efficient solutions.

Within each of the development potentials, key factors should be defined, i.e. the phenomena that define it best. They include the industry size, profitability and market coverage. The industry size can be expressed by the number of enterprises operating within a given sector or service type. It is worth paying special attention to the sector of small and medium-size enterprises, which are better adapted to the changing market conditions (Godlewska, 2013; Grosse, 2002). The number of enterprises will allow measuring both the industry size and its fragmentation. Among other dimensions of entrepreneurship, possible to quantify, the following can be taken into account: the number of start-ups, the number (share) of enterprises in industries using ICT, the share of innovation oriented enterprises. Apart from the number of enterprises, the number of non-profit organizations should also be considered in the assessment (see Zygmunt, 2020; 2018; Rogalska, 2018; Piersiala, 2019).

Alternatively, the industry size can be expressed by the number of people employed, which allows for taking the number of the involved workforce into account, regardless of enterprise size. This measure may, however, be burdened by the absence of information on the scale of the sector (enterprise) robotization. The discussed indicator may take the following dimensions: share of employment according to age groups, number (share) of new employees, new jobs created, balance (change) in the number of people employed, number (share) of the employed specialists (e.g. with PhD degree).

Measurement of the industry size can be performed using the revenues earned from the entire activity or, e.g., the sales of products/services, such as innovations. If the attention is focused on revenues from export sales alone, the extent of the company business (domestic foreign) can be determined. As part of this aspect, it is worth considering the following dimensions of indicators: value (share) of the generated gross value added, value (share) of export production, share of the innovation oriented products.

The indicated range of factors is not exhaustive and can be adjusted depending on the specificity of the conducted analysis.

The indicators illustrating the level of productivity or work efficiency, the role of exports in production, as well as other structure and intensity factors can be used in assessing and identifying the level of regional specialisation. Alternatively, more specialized measures, such as location quotients (LQ), can be applied. Location or specialisation measures include a group of measures illustrating the level of regional specialisation. The location factor is one of the commonly used tools in the form of the below formula:

$$LQ_{ij} = \frac{x_{ij}/x_{i0}}{x_{0j}/x_{00}} \quad (1)$$

where:
x_{ij} – value for a *j*-th division (branch, activity) (j = 1, 2, ..., J) in a *i*-th region (i = 1, 2, ..., I),
x_{i0} – total value in a *i*-th region,
x_{0j} – value for a *j*-th division at the country level,
x_{00} – total value at the country level.

The location quotient (*LQ*) reflects the relative degree of a given phenomenon concentration (employment, production, knowledge) in a given industry, in a given territorial unit, e.g., a voivodeship, comparing to a given industry share in this phenomenon in the country. $LQ = 1$ means that the sub-region has the same share in a given industry as the national economy. $LQ>1$ is considered to indicate regional specialisation in a given industry. *LQ* value greater than 1 can also be achieved by the industries with a small share in the regional economy, but high at the background of the entire country. Such a case may be true for the emerging industries, not yet dominating in the region, however, showing higher potential than in other regions or in the country, which proves their relative specialisation and, at the same time, does not ignore the emerging industries (Pander *et al.*, 2014).

The development potential, related to the dynamics of changes, can be assessed using the traditionally calculated dynamics indexes or a relative increment illustrating the percentage change against the base period. Alternatively, in the case of longer periods it is possible to use the average rate of change (*T*) determined as the geometric mean of the values of *k*-th (k = 1, 2, ..., K) diagnostic feature taking the following form:

$$T_k = \sqrt[t-1]{\frac{x_{kt}}{x_{k0}}} \quad (2)$$

where:
x_{kt} – variable value for the last period of the analysis,
x_{k0} – variable value for the first period of the analysis.

The average annual rate of changes observed for a given phenomenon is $(T_k\text{-}1)\cdot 100\%$. A situation in which the phenomenon did not occur in the base year may turn out problematic. This may be the case for the emerging industries. In such situations, a certain conventional level of the analysed phenomenon can be adopted for the needs of *SMSS* construction. It is suggested that it should not be too high, i.e. not higher than 10%.

The list of proposed development potentials along with the assigned key factors is presented in Table 3.

The key factors can be replicated within the first three potentials or selected independently. In *BASE* development potential, the factors can be expressed in the form of absolute values (e.g. number of enterprises) or indicators (e.g. revenues per 1 employee).

When selecting indicators as the numerical characteristics of the key factors, the adequacy and completeness of the available statistical data should be taken into account. One of the most common problems influencing the analysis scope and findings is the broadly understood quality of statistical data. It should be remembered that changing or extending the input data (indicators) may result in, at least, a correction of the results obtained. And in the case of changing the indicators or adding new measures illustrating the information not considered so far, the conclusions may be changed significantly. Therefore, particular importance should be attached to the selection of statistical measures.

When identifying industries (activities) which may form the basis for the development of smart regional specialisations, the level of industry identification is important. The Statistical Classification of Business Activities (PKD Polska Klasyfikacja Działalności; NACE is the EU equivalent) is most often used for this purpose. The industry identification can be performed based on about 270 groups forming 88 divisions and 21 sections.

The next step is choosing a construction method for the synthetic measure of smart specialisation (*SMSS*). As a rule, this stage consists of the following steps:

1. Normalization of variable values (diagnostic features) using the selected method (e.g. standardisation, unitarisation).
2. Determining the function of variable preferences (stimulant, destimulants) and unifying their nature.
3. Determining the weight system.
4. Calculating the value of partial synthetic measures (*SMSS*) for each of the development potentials and identifying the position of each region (country) within the framework of individual measures.
5. Determining the general synthetic measure of smart specialisation and assigning the corresponding final position to the regions.
6. Identifying the initial RSS.

Each of the steps in the synthetic measure construction, using linear ordering methods, has been discussed in the abundant subject literature covering the problems of statistics and econometrics. The presented study does not address the characteristics of the statistical techniques and measures possible to apply. Those interested will find a lot of valuable information in, e.g., the studies analysing the following problems: normalization: Walesiak (2015), Kukuła and Luty (2015); determining the weight system: Bąk (1999); linear ordering methods / synthetic measure of development (in this study referred to as *SMSS*): Hellwig (1968), Dmytrów (2018).

When choosing the techniques used for the purposes of this analysis, the correctness of application as well as the simplicity of construction and clarity of interpretation were taken into account. Ultimately, the applied procedure covered:

1. Normalization of indicator values using the zero unitarization method and obtaining the values of indicators/measures in the range from [0,1], with zero referring to the least and one standing for the most favourable situation. The unitarization of values was carried out according to the following formula:

$$Z_{kij}^{t} = \frac{x_{kij}^{t} - min x_{kij}^{t}}{\max x_{kij}^{t} - min x_{kij}^{t}} \tag{3}$$

where:
Z = (*B, D, S, I*) – phenomena describing one of the development priorities (*B* – Base; *D* – Dynamics, *S* – Specialisation, *I* – Innovation);
x_{kij}^{t} – value of the *k*-th variable for *i*-th region (voivodeship) and for *j*-th branch (NACE division) in a given *t*-th year (period).

2. Determining weights at the level of Z development priorities using the expert method, assigning the highest I innovation priority to the existing database.
3. Computing the value of partial measures using the non-pattern method of standardized (unitarized) sums defined for industries and voivodeships simultaneously (i-th):

$$SMSS_{Zij}^{t} = \sum_{k=1}^{K} Z_{kij}^{t}. \tag{4}$$

In the case of statistical analyses covering one period, the t index can be ignored. However, when our goal is evaluation, more than one period can be selected for the analysis purposes and the dynamic analysis can be conducted assessing the change in the situation of industries and regions by comparing the value of *SMSS* or the position determined on its basis in different years.

4. Calculating the total value for the Synthetic Measurement of Smart Specialisations (*SMSS*) as the sum of partial measures with the weight system:

$$SMSS_{ij}^{t} = \sum_{z=1}^{Z} w_z SMSS_{Zij}^{t} \quad (5)$$

5. Assigning positions to the industries based on the total $SMSS_{ij}^{t}$ value within the framework of each voivodeship.

Assigning to each voivodeship a specific number (e.g. 4) of industries with the highest position constituting their initial smart specialisations.

The results: the unified identification procedure for smart specialisations in Polish voivodeships[1]

The above procedure was used to identify smart specialisations in the industry (NACE Divisions from B to E) of Polish voivodeships. The years 2012–2017 were selected as the analysis period, where 2017 is the year of the analysis. The selection of this period resulted from the availability of statistical data at the time of conducting the analysis. The basic information on the subject scope of the study is presented in Table 4.

The selection of variables was determined by the substantive value of the variables and the availability of statistical data, however, to avoid the potential adverse effects of including too many variables, their number was limited to the key ones. In the presented analysis all indicators within the potential B BASE were defined in absolute terms.

The following weight system was used in the study: *BASE* (0.2) — *DYNAMICS* (0.1) — *SPECIALISATION* (0.3) — *INNOVATION* (0.4). The adopted weights were imposed by the researchers, established in a subjective manner on the basis of substantive knowledge and the defined research objectives, i.e. the identification of smart regional specialisations. The weights reflect the importance of development potentials in identifying smart specialisations. Thus, the highest priority was given to the expenditure on innovative activities (*I*) reflecting the readiness to develop innovative projects. Subsequently, high priority was assigned to regional uniqueness, promoting these sectors of industry which showed specialisation (*S*). The base (*B*), as a picture of the sector size, received the weight of 0.2

[1] The results for industry and the selected services in accordance with 2 digit NACE rev. 2 divisions, including the discussion on an alternative weight system are available in Bal-Domańska *et al*. (2020)

which allowed the correction of location indicators in the case of extremely low or high values. The lowest weight (0.1) was assigned to the intensity of changes (*D*) in the development of industry sectors in the analysed years.

As a result of the analysis based on *SMSS* value for 16 voivodeships and 34 industries, the proposals for industrial smart specialisations of the voivodeships were selected. It was adopted that three industries are proposed as RSS, for which the value of *SMSS* in a given voivodeship reaches its maximum value, i.e. presents the largest identified development potential. The number of adopted industries (not correlated, e.g., by a supply chain) should not be large. Too large dispersion of industries may result in poor identification of the region's priorities.

In Table 5, each industry within a given voivodeship was assigned positions 1, 2 or 3, respectively. For example, the following divisions were selected as RSS for Mazowieckie (MA) Voivodeship: (C10), (D35) and (C19). Ultimately, out of 34 industries, 23 were classified as initial smart specialisations in at least one voivodeship, whereas the division (C29) manufacture of motor vehicles, trailers and semi-trailers without motorcycles was proposed as the leading specialisation taking position 1 in as many as 4 voivodeships (Lubuskie, Małopolskie, Śląskie and Wielkopolskie) and as the second specialisation for Dolnośląskie Voivodeship (in total, it took the position from 1 to 3 for 5 voivodeships).

Comparing these findings with the RSS of voivodeships defined in the strategic document, it should be stated that the majority of identified smart specialisations constituted the basis or element of the voivodeships' RSS. It should also be noted that among RSS there were also those for which the obtained *SMSS* measure indicated low potential. For example, the division (C10) manufacture of food products was proposed as a development direction of smart specialisations for as many as 7 voivodeships. In fact, in each of them it constituted the core component or the element of smart specialisation. Obviously, most often, in addition to the activities covered by the division (C10), the specialisation also included those related to scientific, educational or research activity, as well as the similar or related by the supply chain business activities. Hence, the specialisation in Kujawsko-Pomorskie Voivodeship is: "The best safe food — processing, fertilizers and packaging". In Lubelskie Voivodshop: "Bioeconomy", which covered all types of economic activities based on biotechnologies, in particular plant and animal production, production of feed and agri-food processing, pharmaceutical, chemical industry, renewable energy sources, public health and environmental industries and services (eco-business). In Podlaskie Voivodeship: "Agri-food industry and value chain sectors" perceived as the specialisation core defined by the traditional competitive advantages of the region, such as e.g. dairying, unique natural resources in both national and European scale, as well as the significant scientific potential, especially in the field of life sciences (…).

In turn, Mazowieckie Voivodeship defined its specialisation as "safe food", which covered all undertakings aimed at increasing the quality and safety of food products and also resulting in the improvement of techniques and processes related to the production, storage, distribution and utilization of food as well as the neutralization or reuse of waste from agricultural production and food processing. In Warmińsko-Mazurskie Voivodeship, food manufacturing was reflected in the "high-quality food" specialisation, whereas in Wielkopolskie Voivodeship in "bio-raw materials and food for informed consumers". In Małopolskie, the last of the 7 voivodeships, the selected C10 division can be associated, less directly, with the specialisation "life sciences", within the framework of which the authors indicate that this specialisation includes two value chains describing knowledge and innovation-based development processes in the field of biotechnology and life sciences, i.e. health and life quality and bioeconomy (semi-finished products and products used for the production of pharmaceuticals, cosmetics, food, materials and energy).

Interestingly, also the voivodeships which recorded a low position of division (C10), were developing their specialisations on food-related activities. In Dolnośląskie Voivodeship manufacture of food products was ranked as the 21st smart specialisation (Tab. 6). The fact which convinced the authors of strategic documents to include food among RSS of the voivodeship was, among others, "quite dynamic increase in the value of production comparing to the situation a few years before (by about 40%)" (Marshal's Office of Dolnośląskie Voivodeship 2015). Food industry is also mentioned among smart specialisations of other voivodeships, e.g., Lubuskie (LORT, 2015), Łódzkie, Opolskie, Świętokrzyskie or Zachodniopomorskie.

The received *SMSS* values also allow an overview of the results regarding individual industries. Table 6 compares the values (on a scale 0–100) of partial synthetic measures for individual development potentials (B, D, S, I) and the values of variables representing key factors (P, C and E) normalized according to formula (3), obtained for the division (C10) manufacture of food products in individual voivodeships. Mazowieckie Voivodeship (MA) has the highest potential in the discussed industry, which mainly results from the large number of people working in this industry (P) (the highest value in Poland), but also relatively high revenues from total activity (C) and the largest export in this industry (E). At the same time, it is the voivodeship in which food industry has incurred significant expenditure on innovation.

Food industry is the best industry in Mazowieckie Voivodeship, both in terms of base (*B*) and innovation (*I*). However, taking into account the internationalization of production, among the best industries also the second of the industries identified as smart specialisations (C19) was included — manufacture and processing of coke and refined petroleum products as well as 3 others: (C26) manufacture of computer, electronic and optical products, (C27) manufacture of electrical equipment and (C20) manufacture of chemicals and chemical products (see Tab. 7).

The analysis of changes in conjunction with industry innovation assessment can be a useful tool for identifying the promising industries at an early stage of development. This is an important element of a smart specialisation construction, which is to identify hidden opportunities and to generate novel platforms upon which regions can build competitive advantage in high value-added activities (Balland *et al.*, 2019).

Discussion

The source literature offers various approaches presented in the research on smart specialisations. The latter are defined through the prism of saturation with human capital, knowledge and innovation (Markowska *et al*., 2016; Sobczak & Bal-Domańska, 2013; Sobczak, 2013; Sobczak, 2012) or result from the entrepreneurial discovery process. In the first case, their identification is carried out through the statistical analysis of the resources available in the economy. In the second case, the definition of smart specialisations takes place in the course of an active entrepreneurial bottom-up discovery process with the participation of key partners, research centres, universities, companies and regional authorities (Wojnicka-Sycz, 2020; Gianelle *et al*., 2020). Then the statistical methods are only mentioned as a component of a broader qualitative analysis.

The proposals to apply quantitative methods in the process of designing and implementing regional Research and Innovation Strategies for Smart Specialisation (RIS3) can be found less frequently in the source literature. One of them is the study (Navarro *et al*., 2014) in which the author presents the methodology allowing the identification of homogeneous regions for regional benchmarking.

In the presented study, the authors fill this gap by presenting in detail the possibilities of using multivariate statistical analysis methods in identifying the initial regional smart specialisations (based on NACE rev 2). The authors' own procedure covers the proposals for selecting development potentials and key factors as well as applying the linear ordering methods. Due to the universal nature of the proposed methodology, it can be widely used at the level of subregions, regions and the EU countries in order to identify the initial development potentials or at the stage of monitoring the effects of implementing development strategies or innovation. The methods are discussed in details and seem even understandable for non-specialists which, to some extent, can be valuable to both practitioners and a wide group of addressees.

Conclusions

Statistical methods offer a useful source of knowledge about the resources and capital in the regions, as well as other factors indicating the potential development and competitive advantages, such as high growth dynamics or regional specialisation. Their usefulness is of particular importance at the stage of diagnosing and identifying the areas presenting the highest endogenous potential at the first stage of developing smart regional specialisations (RSS), and also at the stage of monitoring structural changes occurring in the region. According to the assumptions for RSS development, voivodeship strategies do not present a fixed status, but rather take the form of process based on active discovery, monitoring and evaluation as well as modification of the priorities included in the implemented regional policy, which may result in identifying new, earlier unspecified competitive advantages of the region to prioritize their research and innovation resources in order to build critical mass in the areas of existing comparative advantage.

The advantage of the discussed approach is, undoubtedly, the transparency of the obtained results, taking into account the possibility of a comprehensive assessment of the analysed phenomenon, considering various development potentials based on the resources and capital available in the region (*BASE*), (*DYNAMICS*), as well as openness towards applying these solutions which take advantage of knowledge and innovation (*INNOVATION/RESEARCH AND DEVELOPMENT*) and the specialisation of a given industry/branch (*SPECIALISATION*). Moreover, it is possible to extend the analysis by additional aspects. Summarizing the results of the analysis using *SMSS*, it should be highlighted as follows:

– they facilitated collecting synthetic information about the industries in individual regions and, on this basis, identifying the specialisations in voivodeships,

- they offer the possibility of identifying industries (as well as services) in terms of meeting all aspects simultaneously or meeting one of the criteria taken into account,
- they allow identifying the leading industries for any territorial unit, as well as presenting the position of regions according to the selected NACE divisions.

The identified RSS can then become the object of developing RSS connecting all actors creating Triple Helix (i.e. companies, universities and public organizations) (Virkkala *et al.,* 2017), in this case the identification of leading industries may be extended to other (non-industrial) NACE sections. It is also possible to build competitive advantages based on Porter's value chain (Porter, 1985).

Moreover, the identification of development potentials at a supra-regional level allows the unambiguous identification of regional strengths, but also for an outward looking orientation and focus on the search for missing resources and partners in cooperation. As Uyarra *et al.* (2018) suggest, currently the principle of outward orientation is far from being mainstreamed in strategic thinking and embedded in the definition of action plans for smart specialisation.

The limitations of the presented methodology and the research findings include the specificity, quality and availability of statistical data. The presented results refer to industry alone. In the case of service sections, the research covering innovation is not conducted for all sections, which made it impossible to include all economic activities in the study.

Another limitation is the possibility to identify the potentials defined at the level of 2-digit NACE rev. 2 divisions. More detailed data are desirable, however, their availability may be difficult due to statistical confidentiality.

Yet another limitation is the absence of possibility, at this stage, to identify the interdisciplinary character of smart specialization. The development of smart specialisations as value chains requires further work aimed at defining cross-sectoral correlations based on NACE divisions.

The positive aspect is the comparability of potentials between regions and countries. The methodology in the presented form can be used in all EU countries.

The research challenge is seeking regional benchmarks at the EU level and the development of methodology in the context of monitoring regional strategies of smart specialization.

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Annex

Table 1. The list of selected indicators used for the identification of RSS in Polish voivodeships (status in 2019)

Scale of activity	Innovation	Competitiveness	Social potential
Number of people employed	Expenditure on R&D or Expenditure on R&D as % GDP	Export share in sales revenues	Average monthly salary
Revenues from selling products (services)	Share of enterprise sector expenditure on R&D in GDP	Export share of high technology products	Urbanization indicator
Number of registered enterprises Number of registered large enterprises	Enterprise expenditure on R&D per 1 employee Number of people employed in R&D	Share of production for export Export value/1 inhabitant	Population density Average income/expenses per person
Number of new established enterprises	Number of R&D units	Share in creating gross value added	At risk of poverty rate
Number of new jobs	Percentage of innovation active enterprises	Share in creating region's GDP	Percentage of working age population
Value of investment expenditure	Percentage of enterprises that introduced new or significantly improved products	Labour productivity (in euro/1 hour)	Employment rate (professional activity)
Production volume	Share of new or significantly improved products in sales revenues	Productivity (GDP/1 employee)	Unemployment rate
Gross value added	Share of new or significantly improved exported products in sales revenues	Company revenues/1 employee	Percentage of economically active population with higher (technical) education
Export value	Number of patents submitted to the Polish Patent Office or Patents granted by the Polish Patent Office per 1000 inhabitants	New fixed assets and other purchases	Percentage of people aged 25-64 continuing education
Foreign investment value	Percentage of enterprises which submitted patents (inventions, trademarks, industrial designs, utility models) in the Polish Patent Office	Percentage of enterprises with access to broadband Internet (information technologies)	Number of students

Source: authors' compilation based on the website: https://regionalneinteligentnespecjalizacje.eu/ and documents of marshal offices.

Table 2. Selected statistical methods allowing the identification of smart specialisations

Method	Disadvantages	Advantages
Indicator analysis	– assessment and inference based on individual development indicators, – the need to use multiple indicators, their repeated interpretation and comparative analysis	– simplicity of calculations and interpretations – possibility to conduct a detailed analysis of partial indicators
Location indicator (region's specialisation)	– assessment and inference based on individual indicators, – the need to use multiple indicators, their repeated interpretation and comparative analysis	– simplicity of calculations and interpretations – possibility to conduct a detailed analysis of partial indicators – allows assessing the relative importance of a given specialisation against the background of other specialisations
Shift-share analyses	– assessment and inference based on individual development indicators – does not identify the reasons for positive and negative structural and competitive effects of the sector (region) development – does not illustrate the absolute contribution of the sector to the development of the region's economy	– moderate difficulty level – allows simultaneous assessment of the structure and pace of changes in the sector's development factor – indicates the type of interaction between the sector and the region (direction and scale) – allows the assessment of economic sector development against the background of reference area
Synthetic measures, TOPSIS	– requires unification of the development factors preferential function (stimulants, destimulants, nominants), – requires unification of indicator values and orders of magnitude – it is difficult to choose the adequate weight system	– moderate difficulty level – allows taking into account many factors responsible for the development of sectors (regions) simultaneously – allows taking into account the different importance of factors responsible for sector's (region's) development through the use of weights

Table 3. The list of areas included in the analysis of regional smart specialisations

DEVELOPMENT POTENTIALS		KEY FACTORS
BASIC		
I.	BASE	Enterprises and their structure Employment and its structure Export and its structure Sales volume and its structure Other (…)
II. DYNAMICS		Enterprises and their structure Employment Export and its structure Sales volume and its structure Other (…)
III.	SPECIALISATION AND COMPETITIVENESS	Location quotient Productivity / work efficiency Other (…)
IV.	INNOVATION / RESEARCH AND DEVELOPMENT	Innovation level Patents Research and development Other (…)
SUPPLEMENTARY		
V.	INVOLVEMENT	Assessment of enterprise cooperation Involvement of entrepreneurs in the future development of smart specialisations Other (…)
VI.	PRIORITIES	Society Environment Other (…)

Table 4. The analysis metrics aimed at identifying the initial smart specialisations of Polish voivodeships

Period	year of analysis: 2017 dynamics including 2012 innovation activities in the years 2015-2017
Development potentials	BASE (*P* – the employed in the main workplace; *C* – revenues of enterprises from total activity; *E* – net revenues from sale of products, goods and materials for export) DYNAMICS (indexes of the dynamics of variables from BASE priority; base year 2012) SPECIALISATION (location quotient for the variables from BASE priority) INNOVATION (*I* – expenditures for product and process innovations carried out in the years 2015-2017)
Industries Territorial units	34 NACE Divisions (from B to E) 16 Polish voivodeships

Table 5. The list of industries as proposals for initial smart specialisations at least for two voivodeships) of Polish voivodeships selected based on *SMSS*

NACE Divisions	WI	DL	KP	LE	LU	LD	MP	MA	OP	PK	PL	PO	SL	SW	WM	WI	ZP
(C10)	**7**	21	2	3	16	5	2	1	11	14	1	7	9	10	3	3	8
(C29)	**5**	2	27	21	1	13	1	19	14	5	24	23	1	7	24	1	21
(C22)	**3**	4	3	24	18	7	9	10	12	3	7	11	7	18	2	7	11
(C25)	**3**	3	4	13	10	10	4	8	3	2	18	5	5	5	8	10	9
(C31)	**3**	18	8	12	6	16	27	18	16	8	15	15	28	25	1	2	1
(B08)	**2**	13	24	28	11	21	19	29	6	16	3	24	31	1	17	28	18
(C12)	**2**	34	26	31	22	2	7	25	27	28	2	31	32	9	28	11	29
(C16)	**2**	26	23	16	2	24	20	16	8	4	5	9	26	12	4	6	2
(C19)	**2**	24	29	30	26	29	23	3	26	26	27	2	20	14	28	32	24
(C20)	**2**	12	5	5	19	15	3	6	1	10	22	22	15	22	25	17	5
(C23)	**2**	16	18	22	8	11	13	14	2	9	19	19	8	2	12	18	20
(C26)	**2**	11	11	26	3	12	18	4	34	12	23	3	24	19	27	20	22
(D35)	**2**	30	25	4	30	1	6	2	25	11	26	10	11	16	22	12	26
(E39)	**2**	28	20	34	33	34	31	31	23	22	29	31	4	3	5	26	3

Note: WI – number of voivodeships in which the industry was identified as the leading one (position from 1 to 3). DL – dolnośląskie; KP - kujawsko-pomorskie; LE – lubelskie; LU – lubuskie; LD – łódzkie; MP – małopolskie; MA – Mazowieckie; OP – opolskie; PK – podkarpackie; PL – podlaskie; PO – pomorskie; SL – śląskie; SW – świętokrzyskie; WM – warmińsko-mazurskie; WI – wielkopolskie; ZP – zachodniopomorskie.

Source: authors' compilation based on the Statistics Poland database.

Table 6. Summary information for (C10) industry – manufacture of food products (values of all measures are presented on a scale 0-100) by voivodeships

Voivodship symbol	Position in a voivodship	*SMSS*	Development potentials				Key factors *(BASE)*		
			B	*D*	*S*	*I*	*P**	*C**	*E**
MA	1	26.3	62.7	6.8	4.2	29.6	100.0	59.0	29.1
WI	3	11.2	38.4	6.2	5.7	3.0	59.7	35.9	19.6
PL	1	9.9	12.8	6.5	15.0	5.6	17.1	16.1	5.3
MP	2	8.6	19.6	6.9	4.4	6.7	36.6	14.8	7.5
LE	3	8.1	16.4	6.6	10.6	2.5	23.9	8.1	17.3
WM	3	7.9	14.2	6.6	13.5	0.8	21.5	13.9	7.3
LD	5	7.3	19.3	6.3	7.0	1.6	32.7	18.6	6.7
KP	2	7.2	16.8	6.3	7.8	2.1	27.0	16.9	6.5
SL	9	6.6	20.4	6.1	3.0	2.5	40.0	15.5	5.8
PO	7	6.2	17.9	8.5	5.3	0.6	28.1	14.6	11.0
ZP	8	5.2	9.1	5.1	5.5	3.1	14.7	6.4	6.1
OP	11	3.2	4.7	5.6	4.7	0.8	6.8	4.2	3.0
MR	10	3.1	4.8	6.5	4.6	0.3	10.1	3.4	1.0
DL	21	3.0	7.2	5.4	1.6	1.4	13.1	5.6	2.7
PK	14	2.8	6.1	6.0	2.7	0.4	13.2	3.6	1.7
LU	16	2.7	4.3	5.9	3.7	0.4	8.0	2.9	2.0

* normalized values following formula (3) for variables defined in *BASE* development potential.

Source: authors' calculations based on the Statistics Poland database.

Table 7. The list of 10 best industry sectors for Mazowieckie Voivodeship (values of all measures are presented on a scale 0-100)

NACE	*SMSS*	Development potentials				Key factors *(BASE)*		
		B	*D*	*S*	*I*	*P**	*C**	*E**
C10	26.3	62.7	6.8	4.2	29.6	100.0	59.0	29.1
D35	20.6	48.2	7.1	7.2	20.2	42.5	98.3	3.9
C19	19.5	56.9	6.1	9.9	11.3	6.6	100.0	64.1
C26	14.2	16.3	7.9	4.6	21.9	13.9	14.2	20.9
C17	11.2	8.2	7.3	3.2	19.6	12.0	8.3	4.4
C20	10.7	20.4	5.5	4.7	11.7	21.0	19.7	20.4
C27	9.6	20.4	8.5	3.8	8.9	23.4	17.2	20.7
C25	7.0	16.8	7.6	1.8	5.8	34.5	9.9	6.1
C28	6.1	12.1	6.9	2.8	5.5	16.6	10.6	9.0
C22	5.8	14.3	6.7	1.8	4.4	23.1	10.6	9.2

* normalized values following formula (3) for variables defined in *BASE* development potential.

Source: authors' calculations based on the Statistics Poland database.