European Management Studies
Vol. 21, No. 3, p. 18–45, e-ISSN: 2300-8792
https://doi.org/10.7172/2956-7602.101.2

Frugal Innovations: Implementation in Regions of Poland

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Submitted: 13.04.2023 | Accepted: 18.09.2023

Abstract

Purpose: The objective of the study is to assess the complexity of applying the attributes of frugal innovations in innovative enterprises located in three regions of Poland (i.e. A, B and C), as well as to compare the three regions.

Design/Methodology/Approach: The study included 200 large innovative enterprises. The study listed the following number of enterprises belonging to individual regions: A – 154 entities, B – 39 entities, as well as C – 7 entities. Six hypotheses have been stated in the study. The empirical study considered quantitative methods and research techniques, i.e. the Computer Assisted Web Interview (CAWI) survey technique, and statistical analysis of quantitative data. The basic research tools were: the CAWI survey questionnaire, PS IMAGO PRO 7.0 software and Microsoft Excel.

Findings: The study indicated that: (1) in the A and B regions – both in the area of shaping relationships with customers and shaping innovative processes –moderately high values of Indicator of the Complexity of Shaping Relationships with Customers (ICSRC) and Indicator of the Complexity of Shaping Innovative Processes (ICSIP) indicators were recorded, as well as in the C region, the values are moderately low for both indicators, (2) in the A region, there is a higher level of the complexity of applying the attributes of the concept of frugal innovations with respect to shaping relationships with customers and shaping innovative processes than in the B and C regions.

Implications/limitations: In Poland, there are rather favorable conditions for the implementation of the attributes of the concept of frugal innovations – this is indicated by relatively small differences between the A and B regions. Therefore, in theoretically less developed voivodeships from the so-called Polish B region, frugal innovations are implemented. The research conducted indicates that greater emphasis should be placed on spreading knowledge about frugal innovations in the C Region, which can draw on the experience and support of the A region.

Originality/value: The study raises a new issue in domestic science, concerning the implementation of the attributes of the concept of frugal innovations in various regions of Poland, i.e. the A, B and C regions.

Keywords: frugal innovation; innovative process; management; regions; Poland.

JEL: O31

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Suggested Citation: Woźniak, J. (2023). Frugal Innovations: Implementation in Regions of Poland. *European Management Studies*, *21*(3), 18–45. https://doi.org/10.7172/2956-7602.101.2.

Innowacje oszczędne: wdrożenie w regionach Polski

Streszczenie

Cel: celem badania jest ocena złożoności stosowania założeń koncepcji innowacji oszczędnych w innowacyjnych przedsiębiorstwach zlokalizowanych w trzech regionach Polski (tj. A, B i C), a także porównanie tych trzech regionów.

Projekt/metodologia/podejście: badaniem objęto 200 dużych innowacyjnych przedsiębiorstw. W opracowaniu uwzględniono następującą liczbę przedsiębiorstw należących do poszczególnych regionów: A – 154 podmioty; B – 39 podmiotów; C – 7 podmiotów. W badaniu postawiono sześć hipotez. W badaniu empirycznym uwzględniono ilościowe metody i techniki badawcze, tj. technikę badania Computer Assisted Web Interview (CAWI) oraz analizę statystyczną danych ilościowych. Podstawowymi narzędziami badawczymi były: kwestionariusz ankiety CAWI, oprogramowanie PS IMAGO PRO 7.0 oraz Microsoft Excel.

Ustalenia: badanie wykazało, że: (1) w regionach A i B – zarówno w obszarze kształtowania relacji z klientami, jak i kształtowania procesów innowacyjnych – odnotowano umiarkowanie wysokie wartości wskaźników Indicator of the Complexity of Shaping Relationships with Customers (ICSRC) i Indicator of the Complexity of Shaping Innovative Processes (ICSIP), a w regionie C wartości są umiarkowanie niskie dla obu wskaźników; (2) w regionie A jest wyższy poziom złożoności stosowania założeń koncepcji innowacji oszczędnych w obszarach kształtowania relacji z klientami i procesów innowacyjnych niż w regionach B i C.

Implikacje/ograniczenia: w Polsce istnieją dość korzystne warunki do wdrażania założeń koncepcji innowacji oszczędnych – wskazują na to stosunkowo niewielkie różnice pomiędzy regionami A i B. Dlatego w teoretycznie mniej rozwiniętych województwach z tzw. polskiego regionu B również wdrażane są innowacje oszczędne. Przeprowadzone badania wskazują, że większy nacisk należy położyć na szerzenie wiedzy na temat oszczędnych innowacji w regionie C, który może czerpać z doświadczeń i wsparcia regionu A.

Oryginalność/wartość: w opracowaniu poruszono nowe zagadnienie dla krajowej literatury naukowej, dotyczące wdrażania założeń koncepcji innowacji oszczędnych w różnych regionach Polski, tj. regionach A, B i C.

Słowa kluczowe: innowacja oszczędna, proces innowacyjny, zarządzanie, regiony, Polska.

1. Introduction

Choosing the right model for conducting innovative processes – and their subsequent implementation within an enterprise – is not a simple and easy task. It depends on a number of factors and circumstances – both internal and external. In fact, each innovative entity must find its own "golden mean" regarding the implementation of basic processes responsible for creating value for various types of stakeholders – also in line with the concept of frugal innovations.

Therefore, the article focuses on implementing the attributes of the concept of frugal innovations in Polish enterprises and the complexity of the phenomenon from two perspectives: (1) internal – i.e. shaping innovative processes, as well as (2) external – shaping relationships with customers. Frugal innovations seem to be a model that is increasingly needed in enterprises nowadays – both in underdeveloped and highly developed countries. In Poland, frugal innovations can be a mean to provide enterprises (in various

sectors) with specific sustainable development in changing environmental circumstances, which is reflected in easier access to large, homogeneous groups of customers, cost optimization, systematic improvement of quality, as well as focus on the value provided to stakeholders. Frugal innovations can be regarded as a "lever" for the dynamic of the development of innovative enterprises, making them "overtake" other innovative entities that approach innovation processes in a "traditional" way and in line with other, "conservative" models of operation.

The aim of the study is to assess the complexity of applying the attributes of frugal innovations in innovative enterprises located in three regions of Poland (i.e. A, B and C), as well as to compare the three regions.

It is important that the analyses presented in the study are intended to answer the following research question:

RQ1: How do innovative enterprises located in different regions of Poland (i.e. A, B and C) – characterized by a different level of socio-economic and technological development – approach the implementation of the attributes of the concept of frugal innovations?

The research problem is as follows: What is the level of complexity of applying the attributes of frugal innovations in innovative enterprises located in three regions of Poland (i.e. A, B and C), as well as assessing whether there are statistically significant differences between enterprises located in the three regions of Poland in terms of the complexity of applying the attributes of the concept of frugal innovations (with respect to shaping relationships with customers and shaping innovative processes)?

Results of the research will provide knowledge on how Polish enterprises implement the attributes of frugal innovations and whether they are capable to use the potential of the model in developing their business.

The article consists of six main parts, which in turn deal with the following issues: (1) literature review – peculiarity of frugal innovations, (2) research hypotheses, (3) research methodology, (4) empirical results (exposing the following issues: complexity level of applying the attributes of the concept of frugal innovations, and the comparison between three regions, as well as statistical differences between the A, B and C regions in the complexity of applying the attributes of the concept of frugal innovations, (5) conclusions and discussions, as well as (6) limitations and paths for future research.

2. Literature Review – Peculiarity of Frugal Innovations

Focusing on the peculiarity of modern innovations (including the frugal ones), it is worth noting that the innovative activity in contemporary socio-economic, as well as technical and organizational circumstances can take various forms. Some companies focus on maximizing the usability and functionality of innovations without care about the level of costs and the purchase price of innovation for customers/users. Others, in turn, are focused

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on optimizing the efficiency of innovative processes, i.e. they reduce costs while maximizing the value delivered to the environment. It is difficult to state clearly which of the approach is more recommended for implementing by companies nowadays. However, taking into account the current changes – e.g. negative social effects of the COVID-19 pandemic, limitation of the availability of resources on a global scale, as well as social-economic status of individual regions, a decrease in the purchasing power of societies of many countries (e.g. due to the dynamically growing inflation), accumulation of socio-demographic problems, etc. – it is reasonable to direct companies towards the implementation of the attributes of the second of the above-mentioned approaches. In the literature it is called the concept of frugal innovations.

Frugal innovations can be defined in different ways, e.g.:

- This is a kind of "model" of creating new value for individual customers and even entire social groups (e.g. local communities). This is the concept that considers the creation of maximum available value for specific stakeholder groups (Dadlani, Wali & Mukerjee, 2022, pp. 114–116).
- Frugal innovations can be associated with "lean thinking", that results in the reduction of waste resources and time in innovative processes (Janiszewski, 2020, p. 76).
- Frugal operation is economical, diligent and reflects sustainability in the use of resources (Merriam Webster Dictionary, 2022), as well as is simple, uncomplicated and generates low cost (Oxford Dictionaries, 2020).
- The basic attributes of frugal innovations include low costs and at the same time high financial efficiency, as well as meeting the most important needs of users (Makowski & Kidyba, 2018, p. 201; Hossain, 2020, p. 2).
- Frugal innovations are of specific approach to serve consumers with limited resources in emerging and developing markets, as well as in low-growth Western markets (Hyvärinen, Keskinen & Varis, 2016, p. 2).
- Frugal solutions/projects must be designed, manufactured, delivered and maintained to meet the needs of underserved consumers in poor environments (market segments) (Bhatti, 2012, p. 13).
- It is a transition from the "doing more with less" model to the "doing better with less" model (Radjou & Prabhu, 2016, p. 12 et seq.).

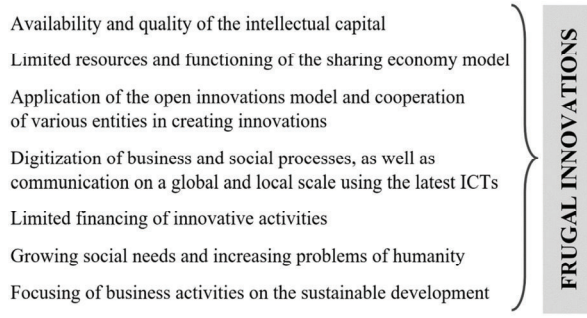
Frugal innovations, as a model for the operation of contemporary enterprises, possess both internal and external sources/determinants which relate to various dimensions of business activities, as well as the socio-economic and technological changes. The basic circumstances of shaping frugal innovations are presented in Figure 1.

Summarizing and at the same time integrating the above content, attributes of frugal innovations can be specified. The basic attributes are as follows (based on: Weyrauch & Herstatt, 2017, p. 8; Markiewicz, Bielawa & Tylżanowski, 2020, p. 26; Dadlani, Wali & Mukerjee, 2022, pp. 26–28):

- low price for the customer and a high availability on the market,
- optimal usability,

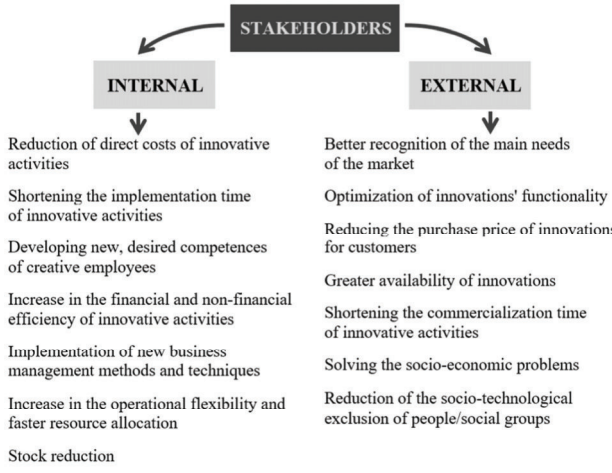
- new idea, new approach, new application,
- reduction of resource consumption, as well as conscious and justified cost reduction,
- drawing on technological development and new scientific knowledge,
- contributing to environmental and corporate sustainability.

Figure 1
Circumstances of shaping frugal innovations



Source: Author's own elaboration based on: Tiwari, Fischer & Kalogerakis, 2017, pp. 13–20; Harris et al., 2020, p. 814; Bhatti & Ventresca, 2012, p. 16.

Figure 2
Significance of frugal innovations for stakeholders



Source: Author's own elaboration based on: Tiwari, Kalogerakis & Herstatt, 2016, pp. 1–2; Tiwari & Kalogerakis, 2016, p. 5 et seq.

https://doi.org/10.7172/2956-7602.101.2

The attributes of frugal innovations listed above are the basis for specific benefits/values received by internal and external stakeholders (Fig. 2). The examples of frugal innovations are: Tata Motors' Nano car, low-cost Swiss Swatch watches, Oppy Mars rover, Five App for deaf-mute people to communicate with friends, Foldscope paper microscope, IKEA furniture, General Electric battery-operated ECG, as well as the MittiCool clay refrigerator (Woźniak, 2022, pp. 31–35; Markiewicz, Bielawa & Tylżanowski, 2020, pp. 28–29; Ratten, 2019, p. 44).

Moreover, it should be noted that the national and international literature is primarily focused on the indication and description of the attributes of frugal innovations implemented in certain types of enterprises. The complexity of application of attributes of frugal innovations in innovative enterprises has not been explored so far (especially in Poland – in terms of identification of the three regions: A, B and C), that points a significant research gap. Therefore, the obtained empirical results will be difficult to compare to the results of other Authors and to conduct discussions.

3. Research Hypotheses

Six hypotheses have been developed in this study. Hypotheses H.1 and H.2 refer to the level of the complexity of applying the attributes of the concept of frugal innovations with respect to shaping relationships with customers, as well as with respect to shaping innovative processes. There are no publications referring directly to Polish circumstances. Nevertheless, strong references to this problem can be found in the foreign literature. Focusing on the relationships with customer (and more broadly – with stakeholders), reference should be made to the research of Bhattacharjya, Bhaduri and Kakoty (2023). They note that "frugal innovation often requires cooperation among heterogeneous actors with diverse values, capabilities, interests and norms". Thanks to the high complexity of the type of activities, it is possible to precisely assess the value provided to stakeholders (including customers). Similar conclusions were reached in the studies by Velananda et al. (2022), as well as Hossain et al. (2022). Nodari et al. (2022), as a result of research, proved that despite specific resource constraints, organizations implement frugal innovations, with a focus on eliminating "excess" costs, and increasing quality of services. It is on the factors that companies should primarily focus in innovation processes. In turn, Barnikol and Liefner (2022) noted during research that institutional and systemic circumstances are particularly important in innovation processes in entities focused on the implementation of the so-called advanced frugal innovations. Mahmood (2014) came to similar conclusions during research. The study by Pedroso et al. (2023) indicates that "social, environmental, economic, and technological aspects of frugal innovation play an important role in the process of idea creation, concept development, product development,

and product marketing". Therefore, the complexity of external factors for enterprises is of great importance in innovation processes. In addition, the relatively high complexity of the implementation of factors determining innovations is highlighted in the research by Qu, Qin and Wang (2023). The authors pay particular attention to factors related to ICTs, but also to: organizational resilience, internal learning from failure, external learning from failure, and design thinking. Significance of the high complexity of ICT factors is also highlighted in the research by Nassani et al. (2022). The authors also highlight the complexity of the relationships with customers in innovative processes in accordance with the frugal model. On the basis, a specification of the hypotheses relating to the Polish circumstances was made. Hypotheses H.1 and H.2 are as follows:

H.1. In all regions of Poland (i.e. A, B, C), there is a high level of the complexity of applying the attributes of the concept of frugal innovations with respect to shaping relationships with customers.

H.2. In all regions of Poland (i.e. A, B, C), there is a high level of the complexity of applying the attributes of the concept of frugal innovations with respect to shaping innovative processes.

At this point, it is worth noting that the H.3–H.6 hypotheses refer to the comparison of three regions of Poland. At this point, it should be emphasized that the regions analyzed have different levels of socio-economic and technological development and it leads to differences in the level of the complexity of applying the attributes of frugal innovations. Such conclusions are prompted by the results of research published by: (Nazarczuk, 2013, p. 100 et seq.; Perło, 2014, p. 101 et seq.; Wojciechowska-Solis, 2018, pp. 122–129; Jędrzejczak-Gas & Barska, 2019, pp. 228–232; Kubiczek & Bieleń, 2021, p. 28 et seq.; Barska, Jędrzejczak-Gas & Wyrwa, 2022, pp. 7–11). Therefore, in this study there is a reasonable comparison of the A, B and C regions. Hypotheses H.3–H.6 are as follows:

H.3. In the A region of Poland there is a higher level of the complexity of applying the attributes of frugal innovations concept with respect to shaping relationships with customers than in B and C regions.

H.4. In the A region of Poland there is a higher level of the complexity of applying the attributes of frugal innovations concept with respect to shaping innovative processes than in the B and C regions.

H.5. Comparing companies from all regions of Poland (i.e. A, B, C), there are statistically significant differences in the complexity of applying the attributes of frugal innovations concept (with respect to shaping relationships with customers) between all three regions.

H.6. Comparing companies from all regions of Poland (i.e. A, B, C), there are statistically significant differences in the complexity of applying the attributes of the concept of frugal innovations (the area of shaping innovative processes) between all three regions.

https://doi.org/10.7172/2956-7602.101.2

4. Research Methodology

4.1. Research Methods

The deductive approach was used – mainly at the stage of critical analysis of national and foreign literature sources. The study used the method of systematic literature review – mainly to synthesize the results of previous research, as well as to identify areas where further research is needed. This is the key stage in creating a theoretical framework for own research. The purpose of a systematic review is to identify all empirical evidence that fits predetermined inclusion criteria to answer a specific research question or hypothesis. By using clear and systematic methods when citing scientific articles and other sources (reports, monographs, etc.), errors can be minimized at the synthesis and inference stage, thus providing reliable results (see: Snyder, 2019, pp. 333–339). The following databases were used for a systematic literature review in the study: Emerald, EBSCO, CEEOL, Web of Science and Google Scholar. The second stage of the research procedure was the specification of the criteria for the selection of papers (mainly scientific articles). The focus was on the following keywords: frugal innovations, frugality, and innovative process. Subsequently, exclusions were made for studies in the following form: industry communications, book reviews, monograph introductions, as well as reports and presentations from scientific conferences. From the collection of 463 publications, only those that referred to the area of interest of economic sciences, in particular management and quality sciences, were selected (86 publications). Subsequently, the content of the abstracts was verified and studies were specified in three groups: directly related to the examined issue (21 publications), partly related to the examined issue (9 publications), as well as poorly related to the research problem (56 publications). In addition, the analyses included publications with the highest citation score (Czakon, 2011, pp. 57–61). The process of systematic literature review was conducted between January 2021 and March 2022. On the basis of the systematic literature review, a specification of the purpose and research problem, as well as hypotheses was made. The key task in relation to own research was the operationalization of hypotheses, it was based on the results of the literature review.

The empirical study primarily considered the inductive approach, and the analysis and synthesis methods (see: Hajduk, 2012, p. 119; Sułkowski, 2012, p. 95 et seq.; Wojciechowska, 2016, p. 116 et seq.), as well as the quantitative research techniques (see: Lisiński & Szarucki, 2020, pp. 123–124). The following quantitative research techniques were used (based on: Sudoł, 2012, pp. 136–145; Apanowicz, 2005, p. 57 et seq.; Zaborek, 2009, pp. 41–49; Wojciechowska, 2011, pp. 47–54): CAWI survey technique, and statistical analysis of data. The basic research tools were: the CAWI survey

questionnaire, PS IMAGO PRO 7.0 software and Microsoft Excel (see: Woźniak, 2022, p. 85).

In the scope of the CAWI study, two basic composite indicators were identified, they were used for quantitative verification of research hypotheses (indicators reflect the level of complexity of enterprises' activities[1]) (see: Woźniak, 2022, pp. 86–90):

- ICSRC – indicator of the complexity of shaping relationships with customers,
- ICSIP – indicator of the complexity of shaping innovative processes.

The indicators were developed using the factor analysis method (the PCA method, the rotation method – Varimax with Kaiser's normalization), and based on 39 detailed measures (Tab. 1)[2] (see: Woźniak, 2022, p. 86). Detailed measures have been identified on the basis of the literature analysis (see: Radjou, Prabhu & Ahuja, 2012, p. 18 et seq.; Mahmood, 2014, pp. 1–4; Radjou & Prabhu, 2016, p. 5 et seq.; Ślęzak & Jagielski, 2018, pp. 81–104; Beaulin, 2019, pp. 8–17; Ratten, 2019, p. 4 et seq.; Markiewicz, Bielawa & Tylżanowski, 2020, pp. 24–41; Bhatti et al., 2022, pp. 21–23, 171–188; de Marchi et al., 2022, pp. 984–1007; Velananda, Dissanayake & Wickramasinghe, 2022, pp. 17–28; Dabic et al., 2022, pp. 914–929).

Table 1
The average scores for the enterprises' activities in all three regions of Poland

Enterprises' activities/detailed measures	Average scores in regions		
	A	B	C
ICSIP – indicator of the complexity of shaping innovative processes			
Reducing the costs of conceptualizing innovations	3.56	3.44	2.71
Reducing the costs of R&D	3.59	3.26	2.71
Reducing the costs of manufacturing	3.73	3.38	2.71
Reducing the costs of commercialization and marketing	3.55	3.54	3.14
Reducing the costs of imitation activities	3.53	3.41	2.86
Reducing the costs of materials and raw materials	3.68	3.33	2.71
Increasing the production efficiency in innovative processes	3.71	3.46	2.86
Increasing the efficiency of financing innovative processes	3.82	3.64	2.57
Increasing the efficiency of marketing activities for innovative processes	3.75	3.46	2.71
Increasing the efficiency of knowledge management in innovative processes	3.82	3.41	2.29

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Table 1 – continued

Enterprises' activities/detailed measures	Average scores in regions		
	A	B	C
Optimization of the employment of people responsible for the implementation of innovative processes	3.69	3.56	2.43
Optimization of employment at managerial positions responsible for the management of innovative projects	3.63	3.64	2.57
Increasing the level of using employee creativity in innovative processes	3.78	3.59	2.71
Developing cooperation with external entities (innovative networks)	3.72	3.54	3.00
Use of outsourcing (external business services)	3.42	3.54	3.14
Reducing production waste	3.64	3.56	2.86
Reducing the negative impact of innovation on the environment (e.g. natural)	3.75	3.59	2.71
Recognizing basic customer needs while complexly penetrating the market	3.73	3.72	3.00
Changes in the value system of society and in the mood of citizens	3.58	3.49	2.43
Social acceptance of innovative activities of enterprises	3.62	3.62	2.57
Emergence of inconsistencies between market reality and the needs of customers/society	3.57	3.28	2.71
Innovation policy in the country and the technology transfer system	3.68	3.49	3.00
Increase in new knowledge (technical, scientific, medical, etc.)	3.71	3.59	3.00
Changes in the structure of industry and/or the market	3.71	3.46	2.57
Changes in the specificity of the innovation process itself and the attributes of innovations	3.63	3.36	2.71
Socio-cultural and demographic situation in the country	3.60	3.23	3.00
Economic situation in the country	3.59	3.46	3.00
Regulations' system in the country	3.55	3.33	2.57
ICSRC – indicator of the complexity of shaping relationships with customers			
Ensuring low costs for customers to acquire innovations	3.58	3.44	2.29
Scaling up the distribution of innovations	3.75	3.41	3.14

Table 1 – continued

Enterprises' activities/detailed measures	Average scores in regions		
	A	B	C
Increasing the usability of innovation	3.75	3.54	2.57
Ensuring the universal and comprehensive nature of innovation for customers	3.73	3.56	2.57
Ensuring the scalability of innovation	3.66	3.36	3.00
Achieving the level of the minimum expected functionality of innovation in the opinion of customers	3.66	3.31	2.86
Ensuring the life span of innovation (long service life of innovation)	3.73	3.44	2.57
Creating innovations for the poorest social groups	3.65	3.21	2.57
Meeting customer needs related to environmental protection, as well as sustainable development of enterprises and the world	3.71	3.41	2.29
Developing alternatives, improvisation and practical methods to overcome a lack of resources or solve seemingly unsolvable financial, social and technological problems of customers	3.78	3.26	2.43
Training customers in the field of self-contained creation of solutions and development of acquired innovations	3.64	3.44	2.43

The interpretation of the average values of the ICSRC and ICSIP indicators was used. The study adopted a simplification of four levels of complexity – the same for both indicators (Woźniak, 2022, p. 114):

- low – values in range <1;2),
- moderate low – values in range <2;3),
- moderate high – values in range <3;4),
- high – values in range <4;5>.

The above ranges of ICSRC and ICSIP values were determined arbitrarily – on the basis of a simple division of the 5-point assessment scale into four equal parts. Of course, it is only the proposal of the author of the study, but it is based on the development of intervals of the same length. This solution seems to be the "fairest". It is worth emphasizing that these are the "conventional" ranges and, in fact, the analysis of various entities (e.g. individual enterprises) may result in a change in the length of the ranges (after taking into account the peculiarity of their operation and the situational context of the analysis). Nevertheless, for the purposes of the study, the division seems to be sufficient – it serves a general (aggregated) assessment of the level of the complexity of applying the attributes of the concept of frugal innovations.

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Moreover, when analyzing the results of the CAWI study, basic descriptive statistics (e.g. median, dominant, mean, standard deviation and skewness) for individual indicators/variables were also considered. The study also used the verification of normality of variables' distribution, the one-way ANOVA, as well as the Bonferroni post-hoc test, and the Kruskal-Wallis test for independent samples.

4.2. Research Sample

The study included 200 innovative enterprises according to PKD (i.e. Polish Classification of Activities) divisions: 10, 11, 13, 14, 20, 21, 26, 27, 29, 52, 59, 61, 62, and 65 (Tab. 2) (see: PKD, 2022). Random selection was used (systematic sampling in layers – the layers were determined by the PKD number) (Rószkiewicz, 2021, pp. 24–26). The condition for qualifying enterprises for the research sample was the implementation of innovative processes[3] during the last five years of operation on the market (i.e. in the period from January 2017 to December 2021), which boiled down to the complete and correct implementation of at least 10 innovations. Only large enterprises were included in the study.[4] The CAWI survey was conducted on a sample of business owners or managers responsible for risk management, innovation processes or project management, employed in enterprises operating in Poland in the most innovative sectors (based on: *Innowacyjność Polski. Chartbook*, 2020, p. 21; *Innowacyjność Polski. Chartbook*, 2021, p. 27) – one respondent from each surveyed enterprise. Overall, the study was conducted between April and July 2022. The CAWI study was carried out (at the level of data collection) by the IPC Research Institute (Wroclaw, Poland) (see: Woźniak, 2022, p. 84, 93–95).

Table 2
Activity profile of enterprises

Activity profile	PKD number	% in research sample
Food & Beverage Manufacturing	10, 11	**10**
Manufacture of textile products and manufacture of clothing	13, 14	**10**
Manufacture of chemicals and chemical products	20	**10**
Manufacture of basic pharmaceutical substances, as well as medicines and other pharmaceutical products	21	**10**
Manufacture of computers, electronic and optical products, as well as manufacture of electrical equipment	26, 27	**10**
Manufacture of motor vehicles, trailers and semi-trailers, excluding motorcycles	29	**10**

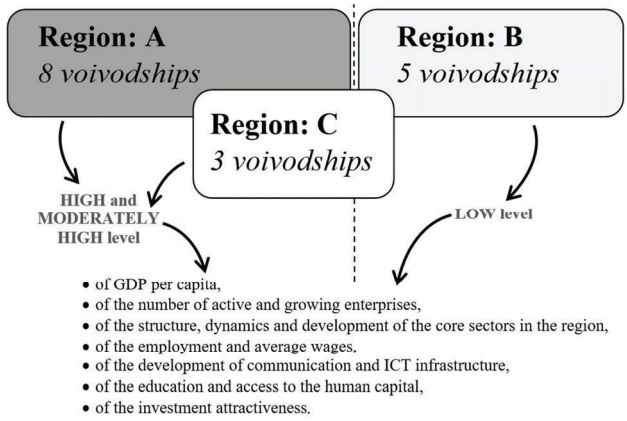
Table 2 – continued

Activity profile	PKD number	% in research sample
Warehousing and service activities supporting transport	52	**10**
Activities related to the production of films, video recordings, television programmes, sound and music recordings	59	**10**
Software, IT consultancy and related activities	62	**10**
Insurance, reinsurance and pension funds, excluding compulsory social security	65	**10**
Total		100

Source: Author's own elaboration based on: PKD, 2022; *Innowacyjność Polski. Chartbook*, 2020, p. 21; *Innowacyjność Polski. Chartbook*, 2021, p. 27).

The study covered entities operating throughout the whole Poland (16 voivodeships). The enterprises were analyzed taking into account the spatial distribution according to the criterion of belonging to the A, B and C regions – reflecting the broadly understood level of socio-economic and technological development (Fig. 3).

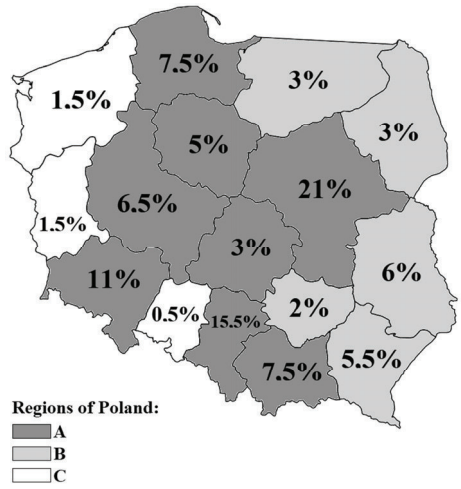
Figure 3
Specification of the A, B and C regions of Poland



Source: Author's own elaboration based on: Mayer & Kapiszewski, 2015.

The A region includes the following voivodeships: Pomorskie, Kujawsko-Pomorskie, Wielkopolskie, Dolnośląskie, Łódzkie, Śląskie, Małopolskie and Mazowieckie, the B region: Warmińsko-Mazurskie, Podlaskie, Lubelskie, Podkarpackie and Świętokrzyskie, and the C region: Lubuskie, Zachodniopomorskie and Opolskie (Mayer & Kapiszewski, 2015). The spatial structure of entities included in the empirical study, regarding the A, B and C regions is presented in Figure 4.

Figure 4
Spatial structure of entities included in the empirical study



The basic criteria distinguishing the regions indicated above are: the level of GDP per capita, the number of enterprises, the structure and dynamics of development of basic sectors in the region, the unemployment and employment rate, the average wages, the level of communication and ICT infrastructure, or the level of education and availability of human capital – constituting the investment attractiveness of a given region (Mayer & Kapiszewski, 2015).

Table 3
Specification of the research sample

Enterprises' attributes		Regions of Poland						Total	
		A		B		C			
		Number	% in region	Number	% in region	Number	% in region	Number	% in research sample
Sector	Industry	88	**57**	27	**69**	5	**71**	120	**60**
	Service	66	**43**	12	**31**	2	**29**	80	**40**
Age	1–5 years ("young")	19	**12**	5	**13**	2	**29**	26	**13**
	6–10 years ("quite young")	52	**34**	21	**54**	2	**29**	75	**38**
	11–15 years ("mature")	32	**21**	5	**13**	3	**43**	40	**20**
	Over 15 years ("old")	51	**33**	8	**21**	0	**0**	59	**30**
Scale of operation	Local (1 city/ municipality/district)	3	**2**	0	**0**	1	**14**	4	**2**
	Regional (1–8 voivodeships in Poland)	18	**12**	4	**10**	0	**0**	22	**11**
	National (9–16 voivodeships in Poland)	75	**49**	22	**56**	3	**43**	100	**50**
	European (min. 1 country in Europe outside Poland)	35	**23**	10	**26**	1	**14**	46	**23**
	International (min. 1 country in the world outside Europe – including Poland	23	**15**	3	**8**	2	**29**	28	**14**
Average annual turnovers	PLN 0–3 million	38	**25**	14	**36**	2	**29**	54	**27**
	PLN 3–6 million	74	**48**	16	**41**	4	**57**	94	**47**
	PLN 6 million and more	42	**27**	9	**23**	1	**14**	52	**26**
	Total	154	**100**	39	**100**	7	**100**	200	**100**

The study listed the following number of enterprises belonging to the individual regions: A – 154 entities, B – 39 entities, as well as C – 7 entities. A detailed specification of the companies included in the research sample is contained in Table 3.

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5. Empirical Results

5.1. Level of the Complexity of Applying the Attributes of the Concept of Frugal Innovations, and the Comparison Between Three Regions

The first problem examined was the assessment of the level of the complexity of applying the attributes of the concept of frugal innovations (Tab. 4).

Table 4
Descriptive statistics for the ICSRC and ICSIP indicators

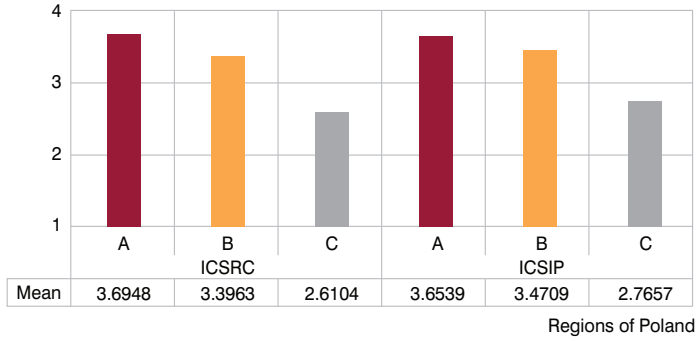
Descriptive statistics	ICSRC			ICSIP		
	Region			Region		
	A	B	C	A	B	C
N	154	39	7	154	39	7
Mean	**3.6948**	**3.3963**	**2.6104**	**3.6539**	**3.4709**	**2.7657**
Median	**3.7273**	**3.3636**	**2.6364**	**3.6566**	**3.5558**	**3.0000**
Dominance	5.00	3.36	3.00	5.00	5.00	3.00
Standard deviation	0.75308	0.99727	0.46566	0.72405	0.85148	0.80159
Variance	0.567	0.995	0.217	0.524	0.725	0.643
Skewness	-0.426	-0.439	-0.092	-0.195	-0.287	-0.970
Kurtosis	0.792	0.089	-2.043	0.181	-0.233	1.286
Gap mark	4.00	4.00	1.18	4.00	3.58	2.44
Min	1.00	1.00	2.00	1.00	1.42	1.28
Max	5.00	5.00	3.18	5.00	5.00	3.72

As it can be noticed, in the A and B regions – both with respect to shaping relationships with customers and shaping innovative processes – moderately high values of indicators were recorded. Within the C region, on the other hand, the values are moderately low for both indicators (Tab. 4). On the basis of the above results, it is possible to falsify the H.1 and H.2 hypotheses, as well as assume that:

- In all regions of Poland (i.e. A, B, C), there is no high level of the complexity of applying the attributes of the concept of frugal innovations with respect to shaping relationships with customers.
- In all regions of Poland (i.e. A, B, C), there is no high level of the complexity of applying the attributes of the concept of frugal innovations with respect to shaping innovative processes.

Comparing all regions (Fig. 5), a specific situation can be noticed – in the A region, there are the highest values for ICSRC and ICSIP indicators – which indicates that in enterprises located in this region of Poland the attributes of frugal innovations are implemented to the greatest extent. However, in the C region, which is an "intermediate" region between the A and B regions, the values of the ICSRC and ICSIP indicators are much lower than in the B region, which is assumed to be the least developed in Poland. Thus, in the B region, a relatively high propensity of enterprises to implement frugal innovations can be observed, and in the C region, there is a weakening of conditions and propensity to conduct innovative economic activities, e.g. in accordance with frugal operations.

Figure 5
Mean values of the ICSRC and ICSIP indicators in each region



On the basis of the above results, it is possible to confirm the H.3 and H.4 hypotheses, as well as assume that:

- In the A region of Poland, there is a higher level of the complexity of applying the attributes of the concept of frugal innovations with respect to shaping relationships with customers than in the B and C regions.
- In the A region of Poland, there is a higher level of the complexity of applying the attributes of the concept of frugal innovations with respect to shaping innovative processes than in the B and C regions.

5.2. Statistical Differences Between the A, B and C Regions in the Complexity of Applying the Attributes of the Concept of Frugal Innovations

Another issue considered was the examination of the occurrence of the statistically significant differences between all regions of Poland (i.e. A, B, C) in the complexity of applying the attributes of the concept of frugal innovations (with respect to shaping relationships with customers and

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shaping innovative processes). The first step was to examine the normality of the distribution of ICSRC and ICSIP variables in each region of Poland. ICSRC and ICSIP variables are normally distributed in all regions (Tab. 5–7).

Table 5
The ICSRC and ICSIP distribution normality test – the A region

No.	H_0	Test	Significance[a]	Decision
1.	The ICSRC distribution is normal with the mean of 3.69 and the standard deviation of 0.75308.	Kolmogorov-Smirnov test for one sample	0.127	**No grounds for rejecting the H_0 hypothesis**
2.	The ICSIP distribution is normal with the mean of 3.65 and the standard deviation of 0.72405.	Kolmogorov-Smirnov test for one sample	0.288	

[a] Significance level is 0.050. Lilliefors method based on Monte Carlo trials (10000) with an initial value of 2000000.

Table 6
The ICSRC and ICSIP distribution normality test – the B region

No.	H_0	Test	Significance[a]	Decision
1.	The ICSRC distribution is normal with the mean of 3.40 and the standard deviation of 0.99727.	Kolmogorov-Smirnov test for one sample	0.185	**No grounds for rejecting the H_0 hypothesis**
2.	The ICSIP distribution is normal with the mean of 3.47 and the standard deviation of 0.85148.	Kolmogorov-Smirnov test for one sample	0.975	

[a] Significance level is 0.050. Lilliefors method based on Monte Carlo trials (10000) with an initial value of 2000000.

Table 7
The ICSRC and ICSIP distribution normality test – the C region

No.	H_0	Test	Significance[a]	Decision
1.	The ICSRC distribution is normal with the mean of 2.61 and the standard deviation of 0.46566.	Kolmogorov-Smirnov test for one sample	0.346	**No grounds for rejecting the H_0 hypothesis.**
2.	The ICSIP distribution is normal with the mean of 2.77 and the standard deviation of 0.80159.	Kolmogorov-Smirnov test for one sample	0.585	

[a] Significance level is 0.050. Lilliefors method based on Monte Carlo trials (10000) with an initial value of 2000000.

Subsequently, the analysis was carried out using the one-way ANOVA method. Verification of hypotheses about the homogeneity of variance for both ICSRC and ICSIP indicators in the three considered regions resulted in a confirmation – so both indicators are characterized by a homogeneity of variance (Tab. 8). In turn, the F test gave rise to the general conclusion that there are statistically significant differences in the values of both indicators between the A, B and C regions (Tab. 9).

Table 8
Homogeneity of variance tests

		Levene test	df1	df2	Significance
ICSRC	Based on the mean	2.315	2	197	0.101
ICSIP	Based on the mean	0.610	2	197	0.544

Table 9
One-way ANOVA – the F test

		Sum of squares	**df**	**Average square**	**F**	**Significance**
ICSRC	Between groups	9.858	2	4.929	**7.715**	**0.001**
	Within groups	125.866	197	0.639		
	Total	135.724	199			
ICSIP	Between groups	5.937	2	2.969	**5.240**	**0.006**
	Within groups	111.616	197	0.567		
	Total	117.553	199			

However, general information on the existence of the statistically significant differences between all regions is not sufficient. It is important to know specifically between which regions there are statistically significant differences. To answer the question, the Bonferroni post-hoc test was used. This test showed that statistically significant differences in the values of both ICSRC and ICSIP indicators do not exist between all regions – they are only between the regions as follows (Tab. 10):

- A and C, as well as B and C – with respect to shaping relationships with customers,
- A and C – with respect to shaping innovative processes.

https://doi.org/10.7172/2956-7602.101.2

Table 10
The Bonferroni post-hoc test

Dependent variable	(I) Region	(J) Region	Difference in means (I–J)	Standard error	Significance	95% confidence interval	
						Lower limit	Upper limit
ICSRC	A	B	0.29853	0.14329	0.115	-0.0474	0.6445
		C	1.08442*	0.30890	**0.002**	0.3385	1.8303
	B	A	-0.29853	0.14329	0.115	-0.6445	0.0474
		C	0.78588	0.32811	**0.050**	-0.0064	1.5781
	C	**A**	-1.08442*	0.30890	**0.002**	-1.8303	-0.3385
		B	-0.78588	0.32811	**0.050**	-1.5781	0.0064
ICSIP	**A**	B	0.18303	0.13493	0.530	-0.1428	0.5088
		C	0.88824*	0.29089	**0.008**	0.1859	1.5906
	B	A	-0.18303	0.13493	0.530	-0.5088	0.1428
		C	0.70521	0.30898	0.071	-0.0408	1.4513
	C	**A**	-0.88824*	0.29089	**0.008**	-1.5906	-0.1859
		B	-0.70521	0.30898	0.071	-1.4513	0.0408

* The difference in means is significant at the level of 0.05.

The Kruskal-Wallis test for independent samples is a confirmation of the analysis using the one-way ANOVA method, which indicated that the ICSRC and ICSIP distributions are not the same for all region categories (Tab. 11). The Kruskal-Wallis test also explicitly indicated that the statistically significant differences are between regions as follows (Tab. 12–13):

- A and C, as well as B and C – with respect to shaping relationships with customers,
- A and C – with respect to shaping innovative processes.

Table 11
The Kruskal-Wallis test for independent samples

No.	H_0	Test	Significance[a,b]	Decision
1.	The ICSRC distribution is the same for all region categories	Kruskal-Wallis test for independent samples	0.001	**Reject H_0 hypothesis.**
2.	The ICSIP distribution is the same for all region categories	Kruskal-Wallis test for independent samples	0.024	

[a] Significance level is 0.050.
[b] Asymptotic significance is presented.

Table 12
Pairwise comparisons for each region – the ICSRC indicator

Sample 1–Sample 2	Test statistics	Standard error	Standardized test statistics	Significance	Adjusted significance[a]
C–B	61.910	23.729	2.609	0.009	**0.027**
C–A	80.425	22.340	3.600	0.000	**0.001**
B–A	18.515	10.362	1.787	0.074	0.222

Each row tests the H_0 hypothesis that the distributions of Sample 1 and Sample 2 are the same. Asymptotic significance (two-sided tests) is presented. Significance level is 0.050.
[a] Significance values for multiple tests are adjusted by the Bonferroni method.

Table 13
Pairwise comparisons for each region – the ICSIP indicator

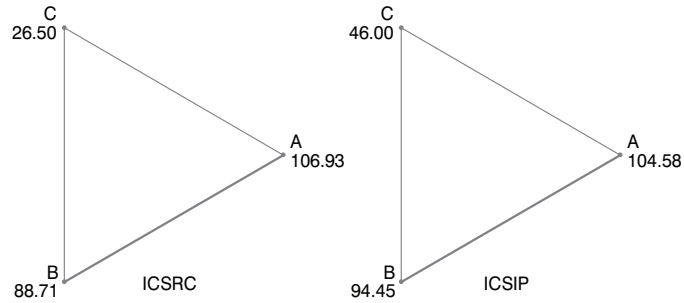
Sample 1–Sample 2	Test statistics	Standard error	Standardized test statistics	Significance	Adjusted significance[a]
C–B	48.154	23.756	2.027	0.043	0.128
C–A	58.584	22.366	2.619	0.009	**0.026**
B–A	10.431	10.375	1.005	0.315	0.944

Each row tests the H_0 hypothesis that the distributions of Sample 1 and Sample 2 are the same. Asymptotic significance (two-sided tests) is presented. Significance level is 0.050.
[a] Significance values for multiple tests are adjusted by the Bonferroni method.

A graphic representation of the statistical differences between the A, B and C regions is included in Figure 6 – the thinner the connection, the stronger statistical differences between the regions.

https://doi.org/10.7172/2956-7602.101.2

Figure 6
Pairwise comparisons for each region –ICSRC and ICSIP indicators



Each node represents the mean sample rank for the region.

On the basis of the above results, the H.5 and H.6 hypotheses can be partially confirmed, as well as it can be concluded that:

- Comparing companies from all regions of Poland (i.e. A, B, C), there are statistically significant differences in the complexity of applying the attributes of the concept of frugal innovations (with respect to shaping relationships with customers) between the A and C regions, as well as the B and C regions.
- Comparing companies from all regions of Poland (i.e. A, B, C), there are statistically significant differences in the complexity of applying the attributes of the concept of frugal innovations (with respect to shaping innovative processes) between the A and C regions.

6. Discussions and Conclusions

Frugal innovations can be a source of a number of benefits for companies operating in various regions of the world (Ratten, 2019), including Poland. Taking into account specific regions in Poland – specified on the basis of the level of the socio-economic and technological development, i.e. A, B and C regions – on the basis of the study, diverse complexity of implementing the attributes of the concept of frugal innovations can be observed. Nevertheless, it can be generally assumed that the phenomenon is not "new" in Poland and is implemented in enterprises at a moderate level. In Poland, there are rather favorable conditions for the implementation of the attributes of the concept of frugal innovations – this is indicated by relatively small differences between the A and B regions. Therefore, in theoretically less developed voivodeships from the so-called Poland B, frugal innovations are implemented. The study also indicated that in the A and B regions – both in the area of shaping relationships with customers and shaping innovative processes –moderately high values of the ICSRC and ICSIP indicators were recorded, as well as in the C region, the values are moderately low for

both indicators. Such situation can be considered beneficial. However, in the C region, which is not the least developed in Poland, the complexity of implementing the attributes of the concept of frugal innovations is the lowest (which does not mean that it is very low at all).

In other words, the study showed that in individual regions of Poland, enterprises implement attributes of the frugal innovation model to a rather different extent. Thus, there is not a fully "uniform" situation in the whole country in this regard. Such a situation may indicate that in the region probably either customers/users/local communities do not report a demand for this type of innovation, or there is no properly developed system for informing about possibilities of implementing the frugal innovation model and the benefits of it – both for enterprises and their external environment.[5] Thus, the research conducted indicates that greater emphasis should be placed on spreading knowledge about frugal innovations in the C region, it can be drawn on the experience and support of the A region. In the case, e.g. tax incentives and supporting industry clusters can be used. Therefore, the results of the study emphasize the need to undertake research at the national (or at least regional) level with respect to systemic improvement of programs and projects aimed at the development of "frugal" innovation activities in the C region. Such solutions also require the development and implementation of specific procedures and regulations (concerning e.g. the applying for funding for the development of innovative activities in accordance with the "frugal" model – this is due to the fact that "transitioning" to the model also requires a reorganization of the enterprise). Developing a campaign promoting the model – along with the indication of measurable benefits may be a useful solution in the long-term "equalization" of the levels of interest in the model of frugal innovations by enterprises in the C region. It should be clearly emphasized that entrepreneurs are not fully aware of the existence of the model and the possibility of its implementation in their internal innovation system in Poland. Therefore, system-wide implications may have a strong impact on solutions dedicated to managers and employees. However, managerial implications are unlikely to exist on their own without systemic (nationwide/regional) support. First, it is necessary to prepare an appropriate "ecosystem" for "frugal" innovative activities, and only then show managers the directions of change in their enterprises. This will avoid institutional inconsistencies and "barriers". The above implications are consistent with the research results and recommendations of Mahmood (2014), as well as Barnikol and Liefner (2022), they noted that institutional and systemic circumstances are particularly important in the processes of improving innovative activities in entities focused on the implementation of frugal innovations. This is also in line with the narrative of Pedroso et al. (2023), they expose social, environmental, economic, and technological circumstances of improving processes of conducting frugal innovations.

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It can also be noted that the results of the study are only partially consistent with the results published, e.g. by Velananda et al. (2022), Hossain et al. (2022), as well as Bhattacharjya, Bhaduri and Kakoty (2023). The authors note that it is important and necessary to interact with various entities (mainly customers) and pay attention to the values they expect in developing the model of frugal innovations. However, in empirical studies, the importance and complexity of the implementation of activities in th respect are at a moderately low level. The results obtained are also only partially consistent with the results achieved by Nodari et al. (2022) who argues that the implementation of measures aimed at reducing costs while ensuring the quality of innovations introduced to the market deserves special attention of entrepreneurs/managers. Here, too, an empirical study showed a moderately low level of respondents' assessment. The same applies to the results obtained in terms of the complexity of ICTs-related activities. The importance of the factors and the complexity of their implementation are relatively low in the surveyed companies, while researches conducted by Nassani et al. (2022), as well as Qu, Qin and Wang (2023) suggest that the complexity should be at a high level.

7. Limitations and Future Research

The research limitations are mainly related to the fact that subjective opinions of respondents were analyzed. It was also based on a limited list of factors constituting the basic attributes of the concept of frugal innovations. The study detailed a total of 39 measures/factors. What is more, in the empirical analysis the specifically developed composite indicators (ICSRC and ICSIP) were used, they simplify the real situation and respondents' assessments. It is also worth noting that the study took into account a different number of enterprises qualified for all three regions of Poland.

Further research should focus on identifying the basic classes of enterprises (with low, moderate and high values of the ICSRC and ICSIP indicators) in each region of Poland (i.e. A, B and C), as well as identifying the basic attributes of the enterprises. Such an approach can provide a basis for exposing the dominant types of enterprises in each region. Further research should also be focused on estimating the correlation between enterprises belonging to individual regions of Poland and the attributes of enterprises, as well as the correlation between the enterprises' affiliation to a given region and the complexity of applying the attributes of the concept of frugal innovations.

Acknowledgements

I would like to thank the IPC Research Institute (Wroclaw, Poland) for their support in obtaining empirical data, as well as the Military University of Technology (Warsaw, Poland) for funding the paper (project No. UGB 856/2023).

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and publication of this article.

Endnotes

1 The higher value of the indicator, the higher complexity of actions. All factors (i.e. detailed measures) were assessed by respondents on a 5-point scale (score "1" means a very low level/importance, and score "5" means very high level/importance).

2 The developed indicators (ICSRC and ICSIP) take the form of weighted averages – this is to highlight the most important factors and components in the opinion of respondents and to give them higher weightings. This approach is treated as more reliable than relying on a simple arithmetic mean. In addition, the indicators only present the average assessment by respondents of the factors/actions included in the study, and present a general "picture" of the examined problem. However, one can assume the Cronbach alpha coefficient, as well as the KMO measure, and the Bartlett test as components of the staged validation of both indicators. For the ICSRC indicator, the values were as follows – Cronbach alpha (0.930), KMO measure (0.937), Bartlett test ($p<0.001$). The ICSRC indicator has 1 component. However, for the ICSIP indicator, they were the values – Cronbach alpha (0.963), KMO measure (0.949), Bartlett test ($p<0.001$). The ICSIP indicator has 3 components. Therefore, all the above values allowed for the construction and subsequent analysis of both indicators. In addition, a content validity of the questions in the questionnaire was conducted – this task remained the responsibility of the author of the study (this was done on the basis of the systematic literature review). Criteria of significance and representativeness have been taken into account. On the other hand, the face validity was carried out on a group of 5 deliberately selected entrepreneurs (the so--called subject matter experts), dealing with innovative activities in Poland. In this way, it was determined whether they understood the questions well, and whether their way of perceiving the questions coincided with the intention of the author of the study. The Cronbach alpha measure was taken into account as part of the construct validity (Klimas, 2021, pp. 123–160; Czakon, 2019, pp. 3–10).

3 This is about innovation in general, i.e. not only frugal innovations. The aim of the screening question in the questionnaire was to include innovative units in the broad sense. On the other hand, the survey questionnaire (in the main questions) did not directly ask about the implementation of frugal innovations – mainly because this concept could be unknown to respondents and could mislead them. The study asked only about the attributes of the frugal innovations, which gave grounds to assess properly the complexity of their use in Polish enterprises.

4 This is due to the fact that large enterprises do not have the so-called resource constraints (staff, financial, information, etc.) in innovative processes, and there is greater certainty that they successfully implement innovative processes and implement innovations on the market (see: Maiti et al., 2020, p. 1526 et seq.; Bakhtiari et al., 2020, p. 507 et seq.).

5 This is only the author's guess. This issue requires additional, in-depth research.

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