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ORIGINAL ARTICLE

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Contact to corresponding author: Katarzyna Szopik-Depczyńska, katarzyna.szopik-depczynska@usz.edu.pl

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Katarzyna Szopik-Depczyńska
University of Szczecin, Pland
orcid.org/0000-0002-3054-0660

Izabela Dembińska
Maritime University of Szczecin, Poland
orcid.org/0000-0001-7618-0018

Agnieszka Barczak
Pomeranian University of Technology in Szczecin, Poland
orcid.org/0000-0001-7584-7183

Angelika Kędzierska-Szczepaniak
University of Gdansk, Poland
orcid.org/0000-0001-6760-7809

Maria Fazio
University of Messina, Italy
orcid.org/0000-0003-3574-1848

Giuseppe Ioppolo
University of Messina, Italy
orcid.org/0000-0003-0262-8435

The impact of crowdsourcing and user-driven innovation on R&D departments' innovation activity: Application of multivariate correspondence analysis

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Keywords: *crowdsourcing; innovation; user-driven innovation; research and development (R&D); marketing orientation; customer purchase behavior; multivariate correspondence*

Abstract

Research background: In enterprise practices, innovation management is taking on more and more open forms. New, creative sources of inspiration are being sought. More and more companies are opening up to cooperation with external people or entities, thus entering a path of open innovation and crowdsourcing. This development is facilitated by increasingly large numbers of online and virtual communities. The idea is to use the potential of the crowd — collective intelligence and creativity. As the strategy is still developing, knowledge in this area is limited. There is a paucity of research on the impact of crowdsourcing on R&D departments and their innovative activities.
Purpose of the article: The study aims to determine whether the use of customer support in the form of crowdsourcing affects the innovative activities of R&D departments that implement user-driven innovation (UDI).
Methods: An original questionnaire was used for the study. Fifty-seven R&D departments in Poland participated in the research. A correspondence analysis, performed on the basis of the Burt matrix, was applied for the analysis. The authors also used Cramer's V correlation coefficients. Examination of the acquired correlation coefficients reveals the existence of four distinct categories of enterprises regarding the usage of crowdsourcing and implementation of product innovations, completed R&D projects, employment in R&D departments, and percentage of revenue allocating in R&D works.
Findings & value added: Research has shown that R&D departments positively evaluate the effects of using UDI in market research analyses of customer purchasing behavior. It helps to create or improve products or services offered on the market, especially in the field of customization, using the information from national research and development units at the same time. Their purpose is mainly to increase the product range. The findings can help academics and practitioners improve the body of knowledge about the determinants of innovation activity, especially concerning relationships with customers and user-driven innovation practices.

Introduction

The term "crowdsourcing" was first used by an editor of Wired magazine (Howe, 2006). In that article, titled "The Rise of Crowdsourcing," Howe describes the use of the Internet by organizations to establish cooperation with customers with the goal of creating innovations. At that time, he char-

acterized crowdsourcing as the outsourcing of certain functions traditionally performed by employees to an undefined group of people, taking the form of an open invitation (Howe, 2008). Over time, mainly thanks to the development of the Internet and other information and communication technologies, crowdsourcing is increasingly becoming the subject of not only theoretical research, but also empirical research into its various perspectives and approaches.

Despite the relatively rapid proliferation of the concept of crowdsourcing, there is some semantic confusion indicating that it is complex and vaguely defined. After analyzing over 200 documents, Estellés-Arolas and González-Ladrón-de-Guevara (2012) find over 40 different definitions of the concept of crowdsourcing. However, they are able to identify the following commonly recognised features of a crowdsourcing initiative: a clearly defined crowd, a task with a clear goal, a specific source of the crowd, clearly-defined remuneration to be received by the crowdsourcer, voluntary participation, an open invitation with a variable scope, the use of the Internet. Interestingly, Estellés-Arolas and González-Ladrón-de-Guevara, continuing their research a few years later (2015), do not notice that the set of these features has been expanded. While demonstrating the full complexity of their properties, Karachiwalla and Pinkow (2021) reduce the concept of crowdsourcing to four basic pillars: the task, the company, the crowd, and the system or platform used to connect them. It should also be noted that the term "crowdsourcing" cannot be treated as a synonym of "open innovation." This is confirmed by Cricelli *et. al.* (2022) in their research on the relationship between open innovation and crowdsourcing.

There is a viewpoint that crowdsourcing is not a concept exclusive to modern times. As mentioned by Afuah and Tucci (2012), early instances resembling present-day crowdsourcing can be traced back to the 17th century, when the British government offered a substantial prize of £20,000 to develop a reliable method for determining ship positions at sea. Similarly, in the late 19th century, the government of France introduced a reward system to encourage the discovery of an alternative to butter for the needs of the armed forces. Such competitions comprise a certain form of using the "wisdom of the crowd.” In more recent examples, Toyota used this method in the late 1940s, announcing an open competition for its logo; and then, in 1957, the Australian government organized a competition for the design of the Sydney Opera House.

The conceptual advancement of crowdsourcing has been propelled by the growing integration of the digital and physical realms, stimulated by the continuous progress of the Internet and other information and communication technologies, including the Internet of Things (IoT), virtual reality (VR), metaverse, augmented reality (AR), artificial intelligence (AI), and blockchain. Thus, crowdsourcing is a natural consequence of the increasing openness, inclusiveness and technicalization of science (Zhang *et al*., 2020; Ang *et al*., 2022; Flores & Rezende, 2022).

Crowdsourcing is one way of using the innovative potential of virtual communities. The process of introducing innovations is increasingly the result of external interactions. The development of social media has naturally enabled mass, universal participation in the innovation process, which is becoming more and more social (O'Hern *et al*., 2021), and thus more and more open (Cricelli *et al*., 2022). The source of new innovations is increasingly becoming consumers who have transformed into role-aware, active and creative prosumers. Therefore, an important task for enterprises is not only to build active network communities around themselves or their products, which can take the form of creative communities, but also to effectively stimulate them and create democratic principles of cooperation. Howe (2008) emphasizes the impact that crowdsourcing has on the innovation process, arguing that, as an alternative to the task traditionally performed by company employees, it leads to a democratization of the innovation process. No proposal for ideas or innovative solutions is favored, because crowdsourcing groups are not formally affiliated with the company. At the same time, people participating in crowdsourcing must comprise a diverse group, because diversity is one of the key determinants of the innovation process.

On the one hand, the spread of the concept of crowdsourcing in the practice of enterprises, organizations, institutions, etc., and on the other hand, the paucity of discussion on the theory-generating level, were the impetus to undertake research on this problem. The study aims to determine whether the use of customer support in the form of crowdsourcing affects the innovative activities of R&D departments that implement user-driven innovation (UDI).

To facilitate the achievement of this objective, the following research questions have been formulated:

1) Do companies that have already introduced new, innovative products more often use the opportunity to communicate with users to collect opinions about their products?
2) Do companies that involve users in the innovation process also use crowdsourcing as a strategy for collecting information about their products?
3) Does the size of the R&D department, including the number of employees and the amount of revenue allocated to R&D, determine the need and frequency of communication with users in the form of crowdsourcing in order to collect users' opinions about their products?
4) Is cooperation with other business and scientific entities important for initiating the practice of crowdsourcing in the process of product opinion research in R&D departments?

In the publishing sphere, considerations regarding crowdsourcing can be divided into two groups: There are theoretical considerations concerning the essence of the problem, typology, general premises for development, etc.; and then there are considerations of a practical nature, involving the various possibilities of using crowdsourcing. The present study attempts to analyze the interaction of crowdsourcing practices with the innovative activities of R&D departments, which fits into the second stream of research. Crowdsourcing is regarded as a tool for innovative R&D activity and as a tool for communication with product users. Additional attention was paid to the question of whether innovation stimulates the use of crowdsourcing practices.

The structure of the article is organized in a classic formula. The review of the literature allows for a better understanding of the essence and assumptions of crowdsourcing. At the same time, it provides defining guidelines for empirical research. The empirical material provides data which is becomes the subject of correspondence analysis. The results of the analysis are then discussed, which enabling the formulation of theoretical and practical conclusions.

Literature review

General background

It is understandable that companies look for new forms and sources of inspiration for their innovative activities. It was a natural step to go beyond the boundaries of the organization, to open up to cooperation with people and entities from outside. Openness is presented as the number of different external sources of a company's innovative activity. As the number of external sources increases, the openness of the company increases (Laursen & Salter, 2004; West & Bogers, 2014; Abdelaty & Weiss, 2023; Toroslu *et al*., 2023).

The open innovation paradigm assumes that the development of companies is not only limited to their own research, but includes acquired patents, licenses for inventions, and other innovative solutions from other entities (Chesbrough, 2003; Chesbrough, 2006; Spithoven *et al*., 2013; Chesbrough & Bogers, 2014). Open innovation is, therefore, a deliberate flow of knowledge that accelerates internal innovation within a company. An open approach entails companies embracing the utilization of outsiders' thoughts and technologies within their business operations, while also enabling other companies to benefit from unused ideas (Bagheri, 2018; Stefan *et al*., 2022). By harnessing the expertise and resources of external partners, a company can attain fresh associations of resources, enabling them to innovate and adapt effectively in established or burgeoning markets (Mortara *et al*., 2011; Spithoven *et al*., 2011; Srisathan *et al*., 2023; Usman *et al*., 2023).

The development of an open innovation strategy implies the simultaneous development of various forms of creating and conducting cooperation. The key tool for the implementation of open innovation processes is crowdsourcing, in which the Internet is used to collect knowledge of the crowd in innovation processes (Devece *et al*., 2019; Cricelli *et al*., 2022; Naeem & Di Maria, 2022). Two points should be noted here. First, the use of the Internet should be looked at as a means of creating and transferring knowledge, and thus as a crowdsourcing tool. The Internet is not only used for the consumption of information, but also the creation of opportunities for easy, interactive and cheap participation in various types of tasks, projects, research, etc., on a global scale (Sawhney *et al*., 2005; Mladenow *et al*., 2014; de Mattos *et al*., 2018; Mubarak & Petraite, 2020; Jugend *et al*., 2020;

Palacios-Marqu´es, 2021). The second issue is basing the open innovation paradigm of the issue of collective creativity or collective knowledge, which is legitimized by the crowd theory (Surowiecki, 2004; Larrick *et al*., 2012; Zhitomirsky-Geffet & Maman, 2014; Fiechter & Kornell, 2021). Here the crowd is understood as a mass of people, mainly laypeople, performing their activities, most often in their free time. These activities may involve simple tasks, such as searching for certain information or creating slogans for marketing campaigns, or complex ones, such as solving high-level problems or participating in research and development projects. Such a crowd is not an unruly mob, but a group capable of producing rational, wise decisions. According to Surowiecki (2005), there are three features that make a crowd wise: diversity, independence, and decentralization. Diversity means that crowd members have different levels or types of knowledge, beliefs and experiences. Independence refers to the ability of each crowd member to make independent decisions, without being limited by other members of the crowd. Decentralization entails that each member of the crowd draws their knowledge from their own environment and experience (Rauhut & Lorenz, 2011).

According to Felin *et al*. (2017), an essential aspect in the theoretical comprehension of crowd and openness practices, while establishing a connection with company theories, revolves around the notion of "community". The term "community" typically encompasses a purposefully created, evolving, or unplanned social dynamic that involves interaction, collective gathering, and social influence, which may pertain to a company, its strategy, or innovation endeavors. In this context, the community can play the role of expanding or strengthening rationality. It is known that an individual's knowledge, information, ideas, and rationality are limited. Therefore, a community, a crowd, a collective, etc., can expand these boundaries not only on the basis of a simple mathematical sum, but also on the basis of a synergistic effect.

Afuah and Tucci (2012), studying dependencies in crowdsourcing, believe that local crowdsourcing can improve the efficiency of problem solving. Whether this happens depends on the type of solutions being evaluated, the characteristics of the problem, the accessibility of the crowd, etc.

Numerous empirical studies have been conducted on the subject of crowdsourcing. They were aimed at deepening the knowledge about its essence, conditions of use, mechanisms of operation, etc. Research demonstrates that crowdsourcing, as an innovation strategy, has the versatility to

address diverse and intricate challenges faced by enterprises in a variety of domains, including management (Khan *et al*., 2019), logistics (Mangiaracina *et al*., 2019), services (Schall, 2012), urban (Teirlinck & Spithoven, 2008), the pharmaceutical industry (Thompson & Bentzien, 2020; Schuhmacher & Kuss, 2020; Tóth *et al*., 2021), tourism (Egger *et al*., 2016), food (Mariani *et al*., 2016), music (Steininger & Gatzemeier, 2019), and even responding to the Covid-19 pandemic (Ciasullo *et al*., 2022). Research shows that crowdsourcing is an effective instrument for increasing product innovation. It increases the possibility of the early detection of errors and prompt reactions via corrections in manufactured products in accordance with customer expectations (Kaewchur *et al*., 2013; Chai *et al*., 2022). As a consequence, the cost of designing and/or manufacturing products is reduced. Crowdsourcing can also be viewed from the perspective of external information and data supply to an organization's decision-making ecosystem, particularly in relation to innovation and R&D (Stieger *et al*., 2012; Nevo & Kotlarsky, 2020).

Case studies and specific examples

The Internet operates continuously and enables real-time communication, yet people working in R&D are often used to more traditional ways of contacting the public: through face-to-face contact and organised campaigns, conferences and symposiums. Adjusting to social media can be difficult, but it provides a great opportunity to reach and maintain contact with a much larger group of engaged users. Engaging in contact, exchanging opinions, and fostering discussions can foster trust in the company, thereby positively impacting collaborative R&D activities. This can be achieved on internal or external platforms (Ruiz & Beretta, 2021). The benefit of intermediary platforms is that they make it easier to achieve "critical mass." This can be difficult or even impossible on one's own site due to the high costs associated with promoting an initiative (Toral *et al*., 2009).

Case studies on ideagora offer compelling insights. Ideagora, being one of the Wikinomics models, encompasses markets for ideas, innovations, and individuals possessing distinctive expertise, facilitating the utilization of worldwide knowledge and skills (Tapscott & Williams, 2007). The strength of this type of network is the diversity of intellectual origin. YourEncore provides consulting services for drug development and commercialization. It helps companies find scientists (active or retired) for one-

off assignments. NineSigma connects SMEs, startups, and academic institutions for innovations. It matches problem solvers with seeker companies in a given marketplace (Howe, 2006). One of the first applications of the indeagora model works on a similar principle. It is the InnoCentive platform, launched in 2001 by the pharmaceutical producer Eli Lilly, which allows a broker (Crowdsourcing Brokers) to find a person with specialized competences in order to solve a specific task faced by the organization. There were over 380,000 cooperating scientists from nearly 200 countries in 2017 (the company was aquired by Wazoku in 2020) (Wazoku.com, 2023).

Another possibility is a public contest, the results of which can inspire the generation of new initiatives by anonymous groups of people. Examples of websites that have used such solutions are China's Witkey and Taskcn (Wu *et al*., 2014). Another example is Amazon Mechanical Turk (AMT), which is a crowdsourcing market for small jobs, where employers (known as 'principals') send their jobs (known as 'HIT') to employees. Mechanical Turk user research indicated that 46.80% of users are from the US, 34% from India and 19.20% from other countries. Detailed, separate analyses of US and Indian workers show that the distribution depends on a variety of factors, such as age, residence, education level, gender, income level, etc., and that they are generally young, low-income workers (Khasraghi & Mohammadi, 2012).

An important research trend in the field of innovation-focused crowdsourcing is the analysis of factors, such as motivation, which determine its effectiveness. Martinez (2017) explores the role of knowledge construction for motivation to ultimately lead to creative involvement in a problem. In addition, he studied the indirect effect of trust on knowledge-sharing behavior. Jespersen (2018) conducted a study investigating the impact of design decisions on the outcomes of an innovation system, demonstrating that the ideal crowdsourcing proposal for an innovation system is contingent upon the specific innovation environment it aims to develop. Studies on the role and classification of these factors have been carried out by Zheng *et al*. (2011) and Acar (2019).

Motivational components can be categorized into two main types: external and internal. External examples include finances and publicity, and internal examples include personal development, and entertainment. Research demonstrates that distinct types of motivation exhibit varying degrees of precision and accuracy in yielded solutions. Luo *et al*. (2021), by examining the impact of engagement on the sharing of knowledge creators'

intentions in virtual communities in China, shows that normative and affective engagement can significantly affect the intent of knowledge sharing in the crowdsourcing process. Moreover, they show that reputation, relationships, and reciprocity, as the main types of benefits associated with social exchange, are key elements prior to user engagement. Research has also been conducted into the elements that can affect the success (or lack thereof) of specific crowdfunding platforms (Vignieri, 2020), as well as the decision to employ crowdsourcing, taking into account the path of least resistance theory (Chan *et al*., 2018).

An important subject of research in connection with crowdsourcing is crowdfunding, which plays a crucial role in raising capital for innovative projects. Small entrepreneurs without an established history can find it difficult to access other forms of financing. Often, innovative companies obtain their first funding through crowdfunding platforms and can develop companies and produce products in a more professional manner (Brem *et al*., 2019; Pan *et al*., 2022). The idea of user-driven innovation, discussed in this article, is also connected with open-source communities. They can be considered the natural successors of the original community of hackers and programming visionaries who created the first software for the development of computer traffic yet had no concern for financial profit (Randhawa *et al*., 2019). Open-source communities thrive on social media, which requires a less traditional approach to communication and engagement.

The literature review shows that the theory-based discourse on crowdsourcing as a tool of innovation strategy is becoming more and more lively in the scientific and academic communities. The theory of crowdsourcing is closely interconnected with various other theories, including emerging ones (e.g., Wikinomics and open innovation) as well as well-established and extensively researched theories (e.g., crowd theory, network theory, and prosumer theory). In the case of empirically-focused discussions, the leading research directions are: the interdisciplinary nature of crowdsourcing, forms of crowdsourcing, activating customers in the crowdsourcing process, aspects of motivation, and analysis of the factors determining the crowdsourcing process. Therefore, the present research on the connections between the tools characterizing innovative activities and R&D of enterprises and crowdsourcing fill a research gap.

Research methods

The primary objective of this study, serving as the foundation for the analyses presented below, is to ascertain the key factors influencing the adoption of user-driven innovation concepts within R&D departments in Poland. To accomplish this objective, the research procedure encompasses several stages, as illustrated in Figure 1.

Data collection

The study is grounded in a comprehensive compilation of the most innovative companies in Poland, including those investing in R&D, formulated on the basis of rankings of innovative enterprises prepared annually by leading national magazines and transnational corporations with research and development centers in Poland. From this database (which includes 678 enterprises), companies that use the User Driven Innovation concept have been identified. Based on preliminary telephone conversations conducted with representatives of all the enterprises selected for the study (contacted mainly with R&D department employees), such participation was confirmed by only 20% of the surveyed respondents. The 137 enterprises which thus qualified to progress to the next stage of the survey have been sent an original, electronic questionnaire using Google Forms. However, the CAWI technique of sending online questionnaires has proven to be ineffective. Only 6 questionnaires have been completed and returned. Therefore, the CATI (computer assisted telephone interview) technique has been used to collect data. For this purpose, direct contact has been established with R&D representatives, who answered the questionnaire during a telephone conversation.

Fifty-seven companies agreed to participate via this method (prohibitive factors included time constraints, general reluctance to participate in research, workload, and secrecy), providing a response rate of 41.6%. To establish results which represent the 137 enterprises which utilise UDI and R&D, quota sampling of enterprises for uniquely defined strata has been used. The age of enterprises is important here, as it can be equated with experience both in terms of functioning on the market and in the utilization of UDI in R&D activities. Additionally, the study considers the representation of sections and departments based on the Polish Classification of Activities (PKD codes). In this context, it is presumed that enterprises from

diverse sectors may produce distinct experiences concerning the implementation of UDI in their R&D activities.

An original questionnaire has been developed for the purpose of this study. The choice of statistical methods has been influenced by two factors: firstly, the nature of the variables, which are limited in scope; and secondly, the characteristics of the sample being investigated.

The study uses the structured telephone interview method based on a previously prepared scenario. The answers have been coded. Excel and Statistica 13.0 have been used for data analysis. With the exception of the year of the foundation of the company, all the variables in the study are either ordinal or nominal in nature.

Statistical methods

Correspondence analysis is a process that describes the relationship between two nominal variables (known as simple correspondence analysis — CA) or multiple nominal variables (known as multiple correspondence analysis — MCA). It also describes the relationships between the categories for each variable. In addition to taxonomic interpretation, this method offers the possibility of factorial interpretation: explaining the tendency of the occurrence of a specific configuration of objects by referring to the impact of hidden features, represented by the factors/dimensions obtained as a result of the analysis. On graphs (perception maps), which are cumulative graphs for correspondence tables, points are plotted for each variable and its category. The distances between them reflect the relationship of the categories — similar categories are plotted close to each other.

Correspondence analysis is included, similar to factor analysis or multidimensional scaling, in so-called incomplete taxonomic methods as clusters are identified. From the perspective of social research, one of the advantages of correspondence analysis is that it is used to analyze qualitative data and does not impose special requirements regarding the distributions that the analyzed variables should be subject to. Since the method of multiple correspondence analysis is widely described in the literature (Abdi, 2003; Kroonenberg & Greenacre, 2004; Abdi & Valentin, 2007; Greenacre, 2007; Hwang *et al*., 2009; Abdi *et al*., 2013; Song *et al*., 2016; Bai *et al*., 2017; Kokkoris *et al*., 2020; Cacuci, 2021; Dorado & Almendros, 2021), the description of its procedure is shown in general terms, indicating its steps.

The initial stage in correspondence analysis involves converting the contingency table into a correspondence matrix. The χ^2 metric is then used to determine row and column profiles, row and column weights, and row-column distances. Next, the n-dimensional space that optimally constitutes the points being examined is identified. The consequent configuration is then subjected to rotation to enhance the variance accounted for by each dimension within the space. The next step is to define the matrix profiles; i.e., the matrix profile of the rows and the matrix profile of the columns. The row-column distances are determined using the χ^2 metric (in this case, a weighted Euclidean metric is employed, where the weights are determined as the reciprocals of the corresponding average profiles) for:

a) rows according to the formula:

$$\chi^2 = d^2(h,h') = \sum_j \frac{\left(p_{hj}/p_{h\circ} - p_{h'j}/p_{h'\circ}\right)^2}{p_{\circ j}}, \quad h,h' = 1,\dots,H; \qquad (1)$$

where:
$d^2(h,h')$ the χ^2 distance between h and h′ row;
$p_{hj}/p_{h\circ}$ elements of the row profile;
$p_{\circ j}$ average profile elements of the row;

b) columns from the fomula:

$$\chi^2 = d^2(j,j') = \sum_j \frac{\left(p_{hj}/p_{\circ j} - p_{hj'}/p_{\circ j'}\right)^2}{p_{h\circ}}, \quad j,j' = 1,\dots,J. \qquad (2)$$

where:
$d^2(j,j')$ the distance χ^2 between the j and j′ column;
$p_{hj}/p_{\circ j}$ elements of the column profile;
$p_{h\circ}$ average elements of the column profile;

In subsequent steps, it becomes crucial to ascertain the inertia within the correspondence analysis. Inertia is a metric that quantifies the amount of variation. The overall inertia represents the dispersion of the profiles around their respective centers of gravity. The center of gravity is determined by calculating the average profile of the row and column categories. It is characterized as the weighted average distance χ^2, calculated between the row-column profiles and their respective mean profiles. The formula for determining this distance in the case of rows is as follows:

$$\wedge_h^2 = \sum_h r_h d_h^2 \tag{3}$$

where:

d_h^2 the distance χ^2 between row and its centroid;

r_h the row weight, which represents the total sum of frequencies within a row of the correspondence matrix.

For columns, this calculation is governed by the following formula:

$$\wedge_j^2 = \sum_j c_j d_j^2 \tag{4}$$

where:

d_j^2 the distance χ^2 between column and centroid;

c_j the weight of column.

When analyzing dependencies among multiple variables, it is recommended to employ multivariate correspondence analysis. In this approach, the traditional two-dimensional contingency table is replaced by the Cramer's V. Burt's matrix using an intricate marker matrix, which comprises numerous submatrices that correspond to consecutive variables. The composite marker matrix Z is represented by the following complex matrix:

$$Z = \left[Z_1 Z_2 \ldots Z_Q\right] \tag{5}$$

where:

$Z_1 Z_2 \ldots Z_Q$ the marker matrix for the consecutive variables;

Q number of variables;

A Burt matrix B is calculated using the coming formula:

$$B = Z^T Z \tag{6}$$

This approach yields a symmetrical block matrix. The principal diagonal consists of a diagonal matrix displaying the frequency count for the respective category of the variable. Apart from the principal diagonal, contingency tables exist for every pair of variables.

Materials

In this study, 69 variables illustrating the phenomenon of crowdsourcing were taken into account. Prior to commencing the correspondence analysis, it is essential to assess the interdependency of the variables under investigation. Given that the gathered responses are calculated on a nominal scale, the Pearson χ^2 test of independence was utilized to examine the connection between the variables. The χ^2 statistics values displayed in Table 1 provide insights into the likelihood of rejecting the null hypothesis, which assumes the variables are independent. Twelve variables that satisfied the predetermined criteria were selected for additional evaluation. The table also presents the V-Cramer correlation coefficients, as Cramer's statistic simplifies the interpretation of association estimates for nominal variables. This metric has a range from 0 to +1, facilitating the understanding of the strength of the relationship. As the VC value increases, the association between variables becomes stronger. Therefore, VC estimates are often (should be) reported alongside χ^2 estimates as an indicator of effect size (Kearney *et al*., 2017).

Results

On the basis of the χ^2 test of independence, it can be concluded that all the variables in Table 1 are characterized by statistically significant relationships. Analysis of the values obtained from the procedure of determining the Cramer V-correlation coefficients suggests that a moderate relationship between the variables. Correspondence analysis was conducted using a Burt matrix with dimensions of 17x17. It is important to note that only some variables are represented graphically (a109) — specifically, those that involve a vast number of the company's products. The results are visually represented in a three-dimensional diagram (Figure 2). The results make it possible to characterize the interrelationships among the categories of variable.

The analysis is complemented by a hierarchized classification scheme of variable categories created using the Ward method, which is depicted in Figure 3. The horizontal line marks the point where the grouping terminates. The interception point has been established by analyzing the linkage distance in relation to the clustering steps (Euclidean distance). Integrating

the correspondence analysis with the graph enables a more comprehensive evaluation of the results.

Clusters I and IV allow for the identification of regularities related to variable a109: the use of crowdsourcing - communication with a significant number of users of the company's products in order to measure awareness and collect impressions about the product or service. Companies belonging to cluster I: firstly, often conduct extensive communication with a significant base of their users in order to gain awareness and impressions (a109:4); secondly, empty at least 21 people in the area of R&D (a34:5); and thirdly, have spent no more than 1% of revenue on research and development in the last three years (a55:2). In addition, these companies have implemented sixteen to twenty research and development projects in the last three years. Cluster II is made up of enterprises that employ sixteen to twenty people in the area of R&D (a34:4) and have allocated an unspecified percentage of revenue to research and development in the last three years (a55:1); at the same time, these were enterprises that carried out at least 21 research and development projects (ratio 77:5). Cluster III are enterprises which employ 11 to 15 people in the area of R&D (a34:3) and which have allocated 1% to 2% (a55:3) and 5% up to 10% (a55:5) of revenue to R&D in the last three years. Cluster IV consists of companies that generally have had minimal interaction with product users in terms of gathering consciousness and impressions about their product (a109:1), and are entities employing 1 to 5 people (a34:1) and 6 to 10 people (a34:2) in R&D. This cluster also includes companies which have devoted 3% to 5% of revenue in the last 3 years of activity (a55:4) to the sphere of R&D; and they have completed 6-10 (a77:2) or 11-15 (a77:3) research and development projects.

Discussion

Companies operating in a turbulent, uncertain global market must constantly be aware of the need to create or maintain a competitive advantage through innovation. The global coronavirus pandemic (COVID-19) has accelerated organizations' abilities to adapt with digital innovations, especially where remote customer contact is possible. This process has significantly influenced the development of innovative products and software, largely involving customers and users (Vermicelli *et al*., 2020). The present question is whether the use of customer support in the form of crowdsourc-

ing affects the innovative activities of R&D departments that implement user-driven innovation (UDI).

Review of the literature suggests a positive correlation between crowdsourcing and innovation in R&D departments. The present results corroborate this analysis. The literature also highlights the role of virtual crowds in knowledge transfer and innovation, which is consistent with our research. While crowdsourcing and online social networks are important for innovation, the links between them are poorly understood. Therefore, it is important to explore the potential of online social networks and crowdsourcing as enablers of organisational learning processes to promote organisational development (Palacios-Marqués *et al*., 2021).

There is an ongoing academic discourse on the roles of crowdsourcing and open innovation. Crowdsourcing is sometimes seen as a mode of open innovation within the context of the sharing economy (Vignieri, 2020). Our study supports this view, suggesting that companies should not only rely on their own ideas, but use what is available on the market.

The Internet is not only a way to reach customers with a product, but also an opportunity to get feedback, give customers the chance to co-create a product, and to participate in surveys or tasks. In addition, the Internet offers the possibility to record and monitor the location of the product or user, frequency of use, and other useful parameters. Therefore, researchers are also looking for ways to reduce the time it takes for users to find relevant innovations, potential business partners, experts and conferences (Protasiewicz, 2023, Gurca *et al*., 2023).

Crowdsourcing as a tool for open innovation is also explored in terms of public institutions that use crowdsourcing for the public, in order to develop open social innovation (Randhawa *et al*., 2019). Researchers also propose conceptual models for crowdsourcing innovation from a cybernetics and management perspective (Lin *et al*., 2022). More and more attention is paid to controlling the flow of knowledge, which is also an aspect of open innovation.

On the other hand, it is important to note that some researchers point to diminishing returns on investment in research or R&D, as well as a lack of growth in patents, noting that these do not correspond to increased research employment over time. Therefore, crowdsourcing is indicated as a way to achieve economies of scale in R&D (Callaghan, 2020).

Multidimensional correspondence analysis shows that crowdsourcing significantly contributes to the diversity of ideas and accelerates the innovation process in enterprises, though the impact varies depending on the industry and size of the company.

While a more robust study would include a variety of economic sectors in the research, and remains a suggested avenue for future study, the results here are significant. Though the limitations of the present study require a cautious attitude when making broad generalizations, there is clear evidence that incorporating crowdsourcing into research and development creates an opportunity to increase innovation potential. Companies should consider crowdsourcing as a tool to complement/support traditional R&D methods. However, they must also remember that this raises other challenges, such as ensuring the diversity of the virtual crowd as well as the protection of intellectual property.

The path to crowdsourcing and open innovation can be traveled independently or with the participation of a crowdsourcing platform. Researchers point out that the development of platform-based business is the result of various self-reinforcing and balancing feedback loops that create dynamic system behaviour (Pussinen *et al*., 2023). As traditional approaches to innovation are changing, the role of crowdfunding platforms, therefore, plays an important role.

The literature suggests that crowdsourcing is most commonly used for the innovation of new products. The present study observes a similar pattern in the use of crowdsourcing and communication. While a significant number R&D departments use crowdsourcing to gather awareness and impressions about their products or services, it is also important to consider the perspective of users who want to participate in the co-creation of a product. It is important to understand and cater to users' diverse motivations in order to keep them interested and engaged (Jo & Bang, 2023).

Taking into account customer feedback and user knowledge on the development of products and services is very important for planning, developing and implementing new ideas and innovations. The proposed framework emphasises the importance of a multidimensional approach, which is exemplified by the success of the participating companies.

In sum, it can be said that crowdsourcing is the key factor stimulating innovation in the area of research and development. It offers significant benefits, but also poses challenges that require careful management. These

findings contribute to a broader understanding of the role of crowdsourcing in economic and technological development.

Conclusions

In Poland, the available human capital and technical resources can be used to develop innovations with the involvement of customers and users. Customers can play a decisive role here, and listening to their opinions often saves costs in the innovation process, while being the shortest and easiest route to product innovation. In short, it can be concluded that companies can be innovative when they use crowdsourcing as their main source of innovation.

The research on Polish companies has shown that it is mainly large companies that are keen to use crowdsourcing as a source of knowledge for new products. These entrepreneurs understand that it is a simple and relatively inexpensive way to adapt a product to the needs and preferences of customers. Companies that have already introduced new, innovative products are more likely to use the opportunity to communicate with users to gather feedback on their products. The same conclusion cannot be drawn for small businesses, although they stand to benefit from such innovations due to their limited resources.

Entrepreneurs are increasingly aware that innovation is no longer just the domain of experts. The present research confirms the theory of the wisdom of the crowd. Crowdsourcing requires companies to enter the wider community, build active and dynamic relationships with the community and establish authentic, two-way channels of communication.

Based on the present research conducted, it is not possible to determine unequivocally whether Polish companies that involve users in the innovation process also use crowdsourcing as a strategy for gathering information about their products.

The study finds that crowdsourcing significantly increases innovation in R&D departments. This highlights the key role of external collaboration in generating diverse ideas and accelerating the innovation process. The results are particularly pronounced in specific industries and company sizes, showing varying degrees of impact. The findings highlight the changing dynamics of R&D strategies. By incorporating crowdsourcing, companies can tap into a wider pool of ideas and solutions, leading to more innovative

results. This shift represents a significant evolution in traditional R&D methodologies.

The study finds that the number of employees and the amount of revenue allocated to R&D do not necessarily determine the need for or frequency of crowdsourcing activity geared toward the collection of user opinions about products. The highest activity in this respect was in cluster I, with the lowest in cluster IV. It is worth remembering, however, that outlays do not always translate to the number of projects, but rather their value, which explains why the number of R&D projects is lower in cluster I than in cluster II.

Even companies that spend less than 1% of their revenue on R&D have completed as many as 16 to 20 R&D projects. This is significant evidence of the benefits of crowdsourcing in innovation activity, even for companies with fewer financial resources. It is therefore unsurprising to find crowdsourcing provides an opportunity to be innovative without a lot of external support in the form of grants or subsidies.

The study does not unequivocally demonstrate the relevance of collaboration with other business and scientific entities to the R&D practice of crowdsourcing product opinions; however, an average correlation according to the Guilford Classification is noted in all cases.

Crowdsourcing is sometimes considered a management tool, and customers are seen as 'external members' of the company. The competence and knowledge of employees do not influence the decision to use crowdsourcing. Furthermore, R&D funding is not crucial in this respect. These are very interesting findings, important from both a theoretical and practical point of view, for both entrepreneurs and potential participants/customers.

As noted above, the present study is subject to significant limitations. The sample may not be representative for the entire population of enterprises in Poland, which means that the results may not be universally applicable to all sectors or geographic regions and the nature of qualitative and quantitative measurements of innovation creates inherent uncertainty in the interpretation of results.

As a result, the authors realise that the sample is not representative and the conclusions of the survey cannot be generalised. However, they may be helpful for R&D departments of companies that are already using crowdsourcing or are considering its use. The results of the survey may be the beginning of a fruitful academic discussion on the role of crowdsourcing in innovation creation. Finally, the results can be useful to leaders of

virtual innovation teams. There are no direct interactions in virtual teams, so virtual team leaders often struggle with team coordination on the one hand and trust and consistency among team members on the other.

Investigating the application of the concept of "user-driven innovation" in corporate research and development proves to be highly challenging. It concerns specially protected areas of operation, because it is closely related to R&D activities which area usually subject to intra-organizational secrecy. Obtaining data about these activities therefore requires special determination. The diverse research and development processes, often resulting from the nature of sectoral, economic, social, or legal conditions, forces a different, often individual, approach to the research methods used, taking into account both the aim of the study and the specificity of the explored entities.

From a practical point of view, the present study provides a guide for companies to successfully implement a crowdsourcing strategy. It highlights the need for a balanced approach to incorporating external input while maintaining core R&D functions, ultimately leading to enhanced innovation capabilities.

The implications of the study go beyond specific industries, suggesting a universal application of crowdsourcing across sectors. The approach has the potential to revolutionize the way companies approach problem solving and innovation, offering new opportunities for growth and development.

There is no doubt that crowdsourcing requires further research, both from a theoretical and practical perspective. Future research should focus on all aspects of implementing crowdsourcing as an influencer of innovation, isolating the underlying motives of the crowd, the relationships between the parties involved. It could consider the application of crowdsourcing across industries, geographic regions, and cultural contexts, and its long-term impact on organizational innovation. It would also be important to explore optimal strategies for integrating crowdsourcing into R&D, with careful attention paid to its disadvantages and risks.

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Annex

Table 1. a/ statistical values and their V-Cramer correlation coefficients

Pairs of question		Statistics and probabilities	VCramer correlation (VC)
a109 - Crowdsourcing utilization - disseminating with a substantial quantity of enterprise's product user to obtain knowledge and opinions about the product (user feedback)	a10 - determining whether the company introduced a novel or enhanced product on the market	13,0288 [0,0014]	0,4781
	a11 - the number of product innovations introduced	113,1426 [0,0000]	0,8916
	a12 - Innovation concerned the size or scale of the enterprise	7,8259 [0,0199]	0,3705
	a13 - Introduction of innovation on the national market	1,3373 [0,5124]	0,1532
	a14 - Introduction of innovation on the global market	19,6890 [0,0000]	0,5877
	a15 - The innovations introduced were radical (breakthrough)	1,2847 [0,5261]	0,1501
	a16 - The innovations introduced were incremental (evolutions or improvements)	1,2847 [0,5261]	0,1501
	a17 - Assessing whether the company introduced a novel or substantially enhanced technological process to the market	13,0288 [0,0014]	0,4710
	a18 - Number of technological innovations introduced	2,9849 [0,5604]	0,1618
	a19 - Technological innovations concerned manufacturing methods	1,2048 [0,5475]	0,1454
	a20 - Technological innovations concerned logistics, distribution, and/or quality standards	0,5008 [0,7785]	0,0937
	a21 - Innowacje technologiczne dotyczyły obszaru/-ów:	0,9483 [0,6234]	0,1289
	a22 - Technological innovations concerned support systems (e.g. design programs in R&D, or IT programs in Accounting)	0,9483 [0,6234]	0,1289
	a23 - Technological innovations concerned the area(s): Human resources	0,6789 [0,7122]	0,1091
	a24 - Technological innovations concerned finance	0,5076 [0,7758]	0,0944
	a25 - Technological innovations concerned research and development	1,8830 [0,3900]	0,1818
	a28 - Planned innovations in the field of products and services	1,4615 [0,4815]	0,1601

Table 1. Continued

Pairs of question		Statistics and probabilities	VCramer correlation (VC)
	a29 - Planned innovations in the field of technological processes	1,4615 [0,4815]	0,1601
	a31 - Theoretical and experimental research and development is undertaken primarily to acquire new knowledge about the basics of phenomena and observable facts without direct practical application	0,5001 [0,7788]	0,0937
	a32 - Experimental research and development is undertaken primarily to acquire new knowledge of practical applications; e.g., created and checked in laboratories and experimental cells	0,6647 [0,7173]	0,1080
	a34 - the number of individuals working in the field of R&D	17,5919 [0,0245]	0,3928
	a35 - Number of employees with a PhD	48,9250 [0,0738]	0,6551
	a36 - Number of doctors with a Dr. habil.	15,9026 [0,1025]	0,3735
	a38 - Research and development is undertaken to shorten customer service response time	4,7227 [0,0943]	0,2878
	a39 - Research and development is undertaken to replace old products with new ones	0,1982 [0,9056]	0,0590
	a41 - Research and development is undertaken to increase product range	1,3384 [0,5121]	0,1532
	a42 - Research and development is undertaken to increase the modernity of the product and/or production process	4,0455 [0,1323]	0,2664
	a43 - Research and development is undertaken to increase employee satisfaction	0,9750 [0,6142]	0,1308
	a44 - Research and development is undertaken to to increase user satisfaction	1,1578 [0,5605]	0,1425
	a45 - Research and development is undertaken to reduce harm to the natural environment	0,2929 [0,8638]	0,0717
	a46 - Research and development is undertaken to reduce unit labor costs	3,1986 [0,2020]	0,2369
	a47 - Research and development is undertaken to improve relations with the environment	1,5929 [0,4509]	0,1672
	a48 - Research and development is undertaken to facilitate entry into a new market	0,1982 [0,9056]	0,0589

Table 1. Continued

Pairs of question		Statistics and probabilities	VCramer correlation (VC)
	a49 - Research and development is undertaken to increase production flexibility	0,1993 [0,9052]	0,0591
	a50 - Research and development is undertaken to secure compliance with regulations and standards	3,0735 [0,2151]	0,2322
	a55 - the proportion of revenues dedicated to R&D over the past three years	16,8948 [0,0312]	0,3849
	a57 - R&D benefited from tax reliefs	3,3853 [0,1840]	0,2437
	a58 - R&D benefited from grants	2,8852 [0,2363]	0,2250
	a59 - R&D benefited from preferential loans	1,1933 [0,5507]	0,1447
	a63 - The impact of the availability of support instruments (tax reliefs, subsidies, grants, etc.) on R&D expenditures	1,3132 [0,5186]	0,1578
	a64 - The impact of the availability of qualified staff on R&D expenditures	1,2574 [0,5333]	0,1485
	a65 - The impact of the availability of the stability and transparency of the state's legal and administrative environment qualified staff on R&D expenditures	2,6251 [0,2691]	0,2146
	a66 - The impact of the availability of lower loan costs on R&D expenditures	3,3853 [0,1840]	0,2437
	a68 - The impact of a larger number of offers of cooperation with research and development units on R&D expenditures	1,5339 [0,4644]	0,1640
	a69 - The impact on R&D expenditures of the more effective management of intellectual property rights as a result of R&D activities	2,5793 [0,2754]	0,2127
	a70 - The impact of a shorter patenting process for developed solutions on R&D expenditures	0,9448 [0,6235]	0,1287
	a71 - The impact on R&D expenditures of co-financing costs of procedures related to intellectual property protection	1,5929 [0,4509]	0,1672
	a72 - The impact on R&D expenditures of the availability of benchmarks for the sector, in terms of methods of conducting R&D	1,0583 [0,5891]	0,1363

Table 1. Continued

Pairs of question	Statistics and probabilities	VCramer correlation (VC)
a73 – The impact on R&D expenditures of the possibility of a joint implementation of R&D projects with larger companies	9,2037 [0,0100]	0,4018
a74 - The impact of changes in tax law on R&D expenditures	2,7090 [0,2581]	0,2180
a75 - The impact of changes in accounting law on R&D expenditures	1,2226 [0,5426]	0,1465
a76 - The impact of access to user-created innovations on R&D expenditures	0,0602 [0,9704]	0,0325
a77 - the number of concluded R&D programs	31,0985 [0,0000]	0,5229
a84 - Cooperation with suppliers	0,7265 [0,6954]	0,1129
a87 - collaboration with units affiliated with the Polish Academy of Sciences	6,5156 [0,0384]	0,3381
a88 - Cooperation with universities	1,3773 [0,5022]	0,1554
a89 - Cooperation with national R&D units	0,5000 [0,7788]	0,0937
a90 - Cooperation with foreign R&D units	0,8444 [0,6556]	0,1217
a91 - Internal processes are considered an important information factor for R&D, with or without innovative solutions implemented in the enterprise	0,5330 [0,7661]	0,0967
a92 - Suppliers are considered an important information factor for R&D, with or without innovative solutions implemented in the enterprise	0,6789 [0,7122]	0,1091
a93 - Customers/users are considered an important information factor for R&D, with or without innovative solutions implemented in the enterprise	0,5330 [0,7661]	0,0967
a94 - Competitors are considered an important information factor for R&D, with or without innovative solutions implemented in the enterprise	20,5675 [0,0083]	0,4248
a95 - PAN institutions are considered an important information factor for R&D, with or without innovative solutions implemented in the enterprise	7,7204 [0,2593]	0,2602
a96 - R&D units are considered an important information factor for R&D, with or without innovative solutions implemented in the enterprise	10,5332 [0,0323]	0,3040

Table 1. Continued

Pairs of question		Statistics and probabilities	VCramer correlation (VC)
	a97 – Foreign R&D units are considered an important information factor for R&D, with or without innovative solutions implemented in the enterprise	6,5708 [0,3624]	0,2401
	a98 - Universities are considered an important information factor for R&D, with or without innovative solutions implemented in the enterprise	4,2850 [0,6382]	0,1939
	a99 - Conferences/fairs/exhibitions are considered an important information factor for R&D, with or without innovative solutions implemented in the enterprise	12,5069 [0,1299]	0,3312
	a100 - Industry magazines/publications are considered an important information factor for R&D, with or without innovative solutions implemented in the enterprise	8,1844 [0,2249]	0,2679
	a101 - Scientific and technical associations are considered an important information factor for R&D, with or without innovative solutions implemented in the enterprise	1,0583 [0,5891]	0,1363

b/ χ^2 statistical values and their V-Cramer correlation coefficients

Pairs of question		χ^2 Statistics and probabilities	VCramer correlation (VC)
a109 - Crowdsourcing utilization - disseminating with a substantial quantity of enterprise's product user tobtain knowledge, opinions about the product (user feedback)	a10 determining whether the company introduced a novel or enhanced product on the market	13,0288 [0,0014]	0,4781
	a11 - the number of product innovations introduced	113,1426 [0,0000]	0,8916
	a12 - Innovation concerned the size or scale of the enterprise	7,8259 [0,0199]	0,3705
	a14 - Introduction of innovation on the global market	19,6890 [0,0000]	0,5877
	a17 - Assessing whether the company introduced a novel or substantially enhanced technological process to the market	13,0288 [0,0014]	0,4710

Table 1. Continued

	Pairs of question	χ^2 Statistics and probabilities	VCramer correlation (VC)
	a34 - The number of individuals working in the field of R&D	17,5919 [0,0245]	0,3928
	a55 - the proportion of revenues dedicated to R&D over the past three years	16,8948 [0,0312]	0,3849
	a73 the potential for the collaborative execution of R&D initiatives with a bigger corporation	9,2037 [0,0100]	0,4018
	a77 - the number of concluded R&D programs	31,0985 [0,0000]	0,5229
	a87 - collaboration with units affiliated with the Polish Academy of Sciences	6,5156 [0,0384]	0,3381
	a94 - Competitors are considered an important information factor for R&D, with or without innovative solutions implemented in the enterprise	20,5675 [0,0083]	0,4248
	a96 - R&D units are considered an important information factor for R&D, with or without innovative solutions implemented in the enterprise	10,5332 [0,0323]	0,3040

Figure 1. Research procedure

Figure 2. Three-dimensional perceptual map illustrating the outcomes deriving from the correspondence analysis conducted on a variables whole

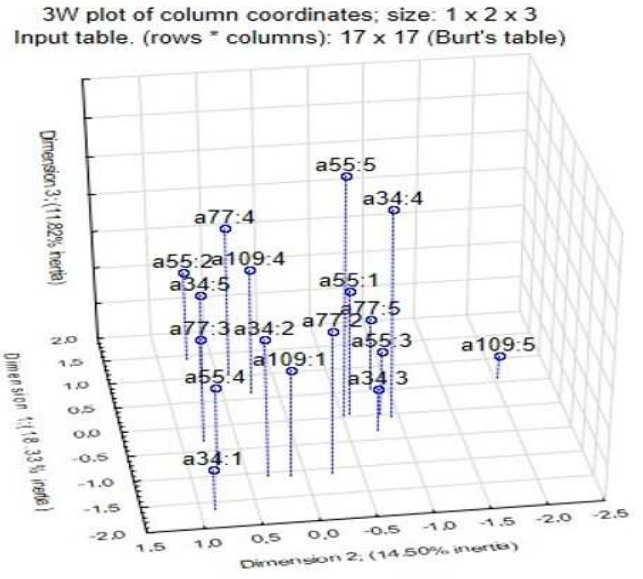

Figure 3. Scheme depicting the hierarchized categorization of variable categories