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Using Data Envelope Analysis for Measurement of Entrepreneurial Network Performance in Manufacturing Firms

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Abstract
The aim of the paper is the analysis of the possibilities of measurement of entrepreneurial network performance in manufacturing firms, using Data Envelope Analysis (DEA) method – a non-parametric approach, allowing for the assessment of the effectiveness of the entrepreneur's social networks in the context of generating information effects. The research uses data obtained from 30 randomly selected Polish enterprises to explore the levels of entrepreneurial networks and their information effects (as performance indicator). The research limitations are the following: the research is limited exclusively to Polish randomly selected entities, and the results cannot be generalized. The originality/value of this paper consists in the fact that this study constitutes both the contribution to the development of the discipline of management and practical guidelines for managers-entrepreneurs since it should be pinpointed that the recognition of the efficiency of gathering information from social networks can be the basis for the conscious creation of the effectiveness of acquiring information from social networks, and thus the conscious use of social networks in economic activity. The novelty of the results presented consists in filling the gap while conducting the research taking into account the assessment of entrepreneurial networks performance using DEA method.

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1. Introduction

The significance of social networks in the business reality is growing. Companies can obtain information, resources, and status by means of network connections, and to understand how these ties work is an important objective of the strategic management research (Kim et al. 2016) in all industries. Simultaneously, in recent years researchers have been showing a great interest in the concept of personal networks in enterprise management and particularly the issue of personal networks of the entrepreneur, indicating a significant role of social networks in sharing information among the connected parties.

While considering some practical aspects of using entrepreneurial networks it is worth pinpointing the manufacturing sector in Poland. Poland is growing as a manufacturing power in Europe. It is the fifth largest manufacturing country in the EU (based on sales figures), with manufacturing contributing to 22.4% of the country's GDP. Leading manufacturing industries include food and beverages; automotive; metal products; rubber and plastic; electrical equipment; chemicals and chemical products; non-metallic mineral products; basic metals; furniture; paper and paper products; machinery and equipment; computer, electronic and optical products (*Advanced Manufacturing*, 2022). According to Reuter's (2023) report, Poland's attractiveness as a destination for inward investment into the manufacturing sector rests on three key pillars: its workforce, its geographic position, and its underpinning infrastructure. These have already helped to propel Poland to become a critical manufacturing nexus within the European Union and created 30 years of expanding Gross Domestic Product (GDP).

Therefore, the relationships of enterprises of the manufacturing sector with other entities are relevant since these ties have a major impact on information, which is gained and used by enterprises of the manufacturing sector. Considering the above and the fact that Polish economy is dominated by small and medium enterprises, it seems reasonable to examine the information efficiency of entrepreneurial networks of small manufacturing firms. The research has previously proven (see: Tomski, 2016) that the entrepreneur's personal network has a positive direct impact on the information effects of this network. The research results presented in this study constitute another step in the analysis of the performance of entrepreneurial networks.

The aim of the paper is the analysis of the possibilities of measurement of entrepreneurial network performance in manufacturing firms, using Data Envelope Analysis (DEA) method – a non-parametric approach, allowing for the assessment of the effectiveness of the entrepreneur's social networks in the context of generating information effects. The variety of possibilities of applying the DEA method to evaluate the activities of various economic entities should be emphasized (eg. Kuzior et al. 2022; Omrani 2023). This method requires few assumptions and opens up possibilities for use in cases where statistical and econometric methods cannot be used. This is often the case when considering goods and services provided in non-market supply. The entrepreneur's social networks are of a non-market nature, and their information efficiency is also not a commodity traded on the market, being at the same time a factor determining the financial and non-financial efficiency of a small enterprise. The use of DEA can therefore be considered adequate to the intended objective. The detailed objectives of the conducted research are selecting companies with the highest and lowest information efficiency of the entrepreneurial network from the surveyed group, identifying firm peers and peer weights, summarizing firm peers and calculating the optimal technology for the company with the lowest efficiency. The approach presented in this study is a model approach, at the same time being an attempt to analyze the information efficiency of social networks of a group of 30 companies with the use of DEA.

2. Information efficiency of entrepreneurial network

All entrepreneurs, while seeking to achieve their own goals, are in constant interaction with the environment and thus cannot be treated in isolation from others. Daily, entrepreneurs contact their family members, friends, employees, business partners, advisers who form their personal (social) networks, considered as one of the most important sources of resources for the entrepreneurial firm (Bratkovic et al., 2009). The concept of 'entrepreneurial network' relates to the personal network of information contacts and exchange relationships utilized by the entrepreneur to create and nurture the business (Witt et al., 2008). Entrepreneurs are also linked to people and organizations that interact with each other and these contacts can extend the availability of resources sustaining a business (Hansen, 1995).

The prior research stresses the significance of networks as a set of resources that provide a competitive advantage to the company (Eisenhardt and Schoonhoven, 1996; Gulati et al., 2000; Lemańska-Majdzik and Tomski, 2013). According to the resource-based view (RBV), the firm's competitive advantage originates in the resources and capabilities the enterprise controls, especially valuable, rare, imperfectly imitable and not substitutable ones (Barney, 1991; Korzh et al., 2017). Resources obtained through networks share the characteristics consistent with the criteria suggested by the RBV. Very important benefits of networks include the access to important and timely information (Adler and Kwon, 2002). Moreover, networks give opportunities for acquiring and exploiting new knowledge necessary for innovation (Yli-Renko et al., 2005; Kuzior et al., 2023; Abdurazzakov et al., 2020).

In the context of the above, it can be said that there is a relationship between the entrepreneurial network and the acquisition of information by the company, which is crucial for its functioning and competitiveness. This relationship has been examined and confirmed by the results of the research, which clearly proved that the entrepreneur's personal network positively affects the information obtained by the entrepreneur regarding opportunities and resources with the potential to take advantage of opportunities, which is also the basis for entrepreneurial management of the company (Tomski, 2016). In this context, an interesting research area seems to be the efficiency of the entrepreneurial network in terms of the triggered information effects. As the researchers emphasize, efficiency is the main economic category used to assess the functioning of business entities or areas of their activity (Kozuń-Cieślak, 2011). In a broad sense, efficiency is defined as the lack of waste and losses, i.e., such a use of resources that contributes to achieving the maximum level of satisfaction possible with specific inputs and technologies (Samuelson and Nordhaus, 2004). The easiest way to define it is the ratio of the achieved effects to the expenditure incurred for this purpose.

Three basic groups of methods are used to calculate efficiency: classical (called index), parametric and non-parametric. The classic approach is to establish performance measures using financial ratios. Parametric methods consist in examining the effectiveness using stochastic or non-stochastic econometric models containing defined parameters (Guzik, 2009). For the assessment, they use the production function, which determines the relationship between inputs and effects. Non-parametric methods use mathematical programming to determine the shape of the efficiency curve but make no assumptions about the functional relationship between inputs and outputs. In addition, they do not consider the impact of the random component on the effectiveness of the tested objects or potential measurement errors (Ćwiąkała-Małys and Nowak, 2009).

3. Research method

For the purposes of this study the DEA method was used. It is a non-parametric approach not requiring any assumptions about the functional form of a production function and a priori information on relevance of inputs and outputs. DEA is a "data-oriented" approach for assessing the performance of a set of peer entities called Decision-Making Units (DMUs), which convert multiple inputs into multiple outputs (Cooper et al. 2011). The relative efficiency of a DMU is measured by estimating the ratio of weighted outputs to weighted inputs and comparing it with other DMUs. DEA enables each DMU to choose the weights of inputs and outputs maximizing its efficiency. The DMUs achieving 100% efficiency are found efficient while the other DMUs with efficiency scores below 100% are inefficient. For every inefficient DMU, DEA identifies a set of corresponding efficient DMUs called a reference set which can be used as benchmarks for improvement. DEA also enables the calculation of the required number of improvements in the inefficient DMU's inputs and outputs to make it efficient (Lee and Kim, 2012). The justification for using the DEA method is, among others, its high usefulness for measuring various aspects of efficiency, which was emphasized by Adamczyk and Nitkiewicz (2008).

DEA was firstly introduced by Charnes et al. (1978). DEA is a linear programming technique where the set of best-practice or frontier observations are the ones for which no other decision-making unit or linear combination of units achieves the same or higher level of every output (for the given inputs level) or uses the same or lower level of every input (for the given outputs level) (Berger and Humphrey, 1997). DEA models are widely applied as a tool for estimation of efficiency, performance, or productivity of homogenous decision-making units. Such effects can be denoted as the outputs of the decision-making units (Halkos and Salamouris, 2004). Various types of DEA models are known in the literature. However, the two most often used ones are the CCR model (after Charnes, Cooper, and Rhodes, 1978) and the BCC model (after Banker, Charnes and Cooper, 1984). The treatment of returns-to-scale represents the central dissimilarity between the two models (Jemric and Vujcic, 2002): BCC model permits variable returns-to-scale while CCR model only allows constant returns-to-scale. Efficiency measurement for each DMU in CCR model is attained as a maximum of a ratio of weighted sum of outputs to weighted sum of inputs.

The DEA CCR model introduced by Charnes, Cooper and Rhodes assumes constant returns to scale (CRS), meaning any change in inputs should result in a proportional change in output. The model applies the mathematical programming optimization method to determine the efficiency of a DMU (Decision Making Units) dividing the weighted sum of outputs (virtual output) by the weighted sum of inputs (virtual input). The CCR CRS model proposed by Charnes, Cooper and Rhodes is also the most popular DEA model used in the practice of empirical research. The economic, organizational, or social analyzes carried out on its basis usually concern the determination of efficiency and benchmarks. In the case of the analysis of the information efficiency of entrepreneurial networks, constant returns to scale were assumed, because no research results were identified that would indicate the possibility of occurrence of variable returns to scale. Data obtained on the Likert scale were used for the calculations, as suggested by Cook and Zhu (2006), who developed a general framework for modeling and treating qualitative data in DEA and provided a unified structure for embedding rank order data into the DEA framework. The software DEAP version 2.1 was used for the calculations.

4. Research sample

The research, the results of which have been presented in the this study, was based on the method of conducting empirical studies through managerial perception (Miller, Friesen, 1978), in which data are obtained with the questionnaire. The conducted research is exploratory in nature, directed to the identification of entrepreneurial networks and their information effects (network performance in terms of gathering information useful for business purposes).

The respondents were the owners-managers of the studied small and medium manufacturing enterprises. The research tool was distributed among the randomly selected organizations. 35 copies of the completed questionnaires were obtained, 5 of which were rejected on account of incomplete data. In these circumstances, the research sample was 30 companies.

The majority are the companies conducting their business activity in cities. These entities amount to 80%, whereas the companies operating in the country constitute 20%. The enterprise operating on the market for the shortest time is 27-month-old. The oldest has been operating on the market for 26 years. The companies under study are both companies characterized by self-employment, the ones not employing workers and those employing even 46 people. On average, the level of employment in the companies amounts to 23.5 employees. For the surveyed entities, the basic activity is production (100%).

The research is based on the existing achievements of management science. In order to operationalize the entrepreneur's personal network, the measurement of the frequency of interaction (related to conducting general conversations about business and economy) of the entrepreneur with members of their personal network was used (compare Sawyerr and McGee 1999). Individual components (actors and groups of actors) included in the personal network of the entrepreneur were identified. The network created with the entrepreneur's closest family members and friends was omitted - due to the redundant nature of information from such networks. The highlighted groups and the subnets they create are (Peltier and Naidu; 2012; Zali et al., 2012; Schott, 2010, Schott, 2009; Zhao et al., 2010): market network (customers C_KL_ZL; suppliers, service providers C_DO_US; the entrepreneur's acquaintances, owners and people related to other companies not being competitors (not customers and not suppliers C_PB_NKON; the entrepreneur's acquaintances, owners and people related to other companies being competitors (not customers and not suppliers!) C_PB_KON), administrative network (acquaintances related to administration, authorities and the public sector, officials, controllers, etc. C_ADM), professional network (friends related to organizations supporting business (investors, advisors, bankers, accountants, lawyers, etc.) C_WSP_BIZ), occupational network (former associates (work colleagues), previous boss, current associates (work colleagues), current boss (employment and running a business) C_EX_WSP) and experience network (friends with relevant experience in starting new businesses and running a business, scientists, inventors C_DOSW). To sum up, the entrepreneur's personal network was operationalized with a question related to all the listed groups belonging to the entrepreneur's personal network: *Over the last three years, how often have you had general conversations about issues related to business and economy with people belonging to the particular groups?* It was possible to provide answers on an eight-point Likert scale, where 1 meant "very rarely", 7 - "very often", and 0 meant no interaction of the entrepreneur with a given group in terms of discussions about issues related to business and economy.

The measurement of the information effects of the entrepreneur's personal network was made based on a proprietary tool developed on the basis of the works by R. Krupski (2011). At the same time, the tool used is in line with the suggestions contained in the research on the impact of the knowledge network on the performance of the enterprise. In these studies (cf: Solymossy 2000), the attention is paid to the importance of information and knowledge obtained from the network, affecting: solving technical problems, broadening knowledge about the market and competitors, gaining access to new distribution channels, acquiring financial resources, and providing new customers, etc. The information effects of the personal network were based on information about resources that were distinguished by Krupski (2011) as relatively original resources (in Barney's sense: valuable, rare, difficult to imitate and difficult to substitute) (compare Krupski, 2011, s. 49; Krupski, 2006), on which a relatively sustainable competitive advantage can be built, i.e., strategic resources (Krupski, 2011). At the same time, these are resources with the potential to take advantage of opportunities and neutralize threats (Krupski, 2006; Krupski, 2008). Among these resources, the following were distinguished (Krupski, 2011): knowledge (EIS_ZAS_1) and employee skills and talents (EIS_ZAS_2), employee attitudes and behavior, motivations and other elements of organizational culture (EIS_ZAS_3), privileged, formalized relations with the environment (EIS_ZAS_4), privileged, informal relations with the environment (EIS_ZAS_5), industry technologies (EIS_ZAS_6), information technologies supporting industry technologies and information and decision-making processes (EIS_ZAS_7), own or available natural resources (EIS_ZAS_8), location (EIS_ZAS_9), the company's image (EIS_ZAS_10), sources of financing (EIS_ZAS_11), routines, intra-organizational solutions (EIS_ZAS_12). The proprietary tool used to measure the information effects of the personal network was developed based on the above enumerations (the markings of the scales relating to the listed resources and opportunities are given in brackets). The entrepreneurs were asked to answer the question to what extent the information they obtained in the last 3 years allowed them to use the above-mentioned resources or take advantage of the opportunities described above. The answers were given on a seven-point Likert scale, where 1 meant "didn't allow", 2 - "small", and 7 - "very big". This tool allowed for examining the acquisition of information by the entrepreneur from their personal network. In this way, information about resources that lead to endogenous growth resulting from the resources used by the company was identified. The obtained results in terms of the levels of 8 subnetworks of entrepreneurial networks and the levels of 12 information effects were the input and output variables for the DEA model construction.

5. Research Results

The findings and the interpretations for multi-stage based *constant returns to scale (CRS)* DEA are presented in this chapter. Input variables are the levels of 8 subnetworks of entrepreneurial networks created by small business owners-managers with the actors of their environment while the output variables are 12 information effects of the networks. The individual enterprises subjected to the analysis were marked with the identifiers from F1 to F30.

In the first step, the comparative analysis of network efficiency was conducted. The efficiency of the entity is determined by the optimal multiplier of the level of inputs. The results of the analysis, adequate to the applied input-oriented CRS model, are presented in Table 1.

Table 1. Efficiency summary

Firm ID	Efficiency	Firm ID	Efficiency
F1	0.833	F16	0.452
F2	1.000	F17	0.829
F3	0.468	F18	0.833
F4	1.000	F19	1.000
F5	0.667	F20	0.829
F6	1.000	F21	1.000
F7	1.000	F22	1.000
F8	0.848	F23	0.346
F9	1.000	F24	0.337
F10	1.000	F25	1.000
F11	1.000	F26	0.926
F12	1.000	F27	0.652
F13	0.916	F28	0.808
F14	0.943	F29	0.769
F15	0.846	F30	0.643
Mean: 0.832			

The obtained results revealed that entrepreneurial networks of 12 companies out of 30 surveyed ones achieve maximum efficiency (efficiency value of 1,000), which amounts to 40% (identifiers of companies with maximum efficiency are marked in gray in the table). Other firms (18 companies, i.e., 60%) have the values of less than 1.000 which shows the need to improve their input variables. This is possible by either decreasing or increasing the input levels. The results of the conducted analysis indicate that 19 (63%) enterprises achieve network efficiency above the average for the surveyed population, and the network efficiency of 11 (37%) enterprises is below the average level for all the respondents. Enterprises F2, F4, F6, F7, F9, F10, F11, F12, F19, F21, F22 and F25 are fully effective. The least effective is the F24 company, the efficiency of which is 33.7% of what it could achieve if its "technology" of obtaining information from the entrepreneur's network was constructed on the model of the technology of the best companies. The same is true for F1, F3, F5, F8, F13, F14, F15, F16, F17, F18, F20, F23, F24, F26, F27, F28, F29 and F30. In case of F1, they need to improve the network efficiency by 16.7%, F3 needs to improve its network efficiency by 53.2%, F5 by 33.3%, F8 by 15.2%, F13 by 8.4%, F14 by

5.7%, F15 by 15.4%, F16 by 54.8%, F17 by 17.1%, F18 by 16.7%, F20 by 17.1%, F23 by 65,4%, F24 by 66.3%, F26 by 7.4%, F27 by 34.8%, F28 by 19.2%, F29 by 23.1% and F30 by 35.7%. As a group, the enterprises need to improve their average network efficiency by 16.8%.

The next step of the conducted research was peer (reference) analysis. The summary of peers and peer weights is shown in Appendix Table 1. The results allowed for the identification of peers and the indication of optimal technologies for individual ineffective enterprises. Therefore, the optimal technologies for individual ineffective enterprises in terms of information effects of entrepreneurial networks were determined in relation to the technologies of enterprises with the highest relative efficiency. The research depicted that the inefficient firms should follow the input-output trend of the efficient enterprises. The efficient ones do not have to follow any firm. Furthermore, peer weights were identified, which allows for the creation of benchmarking formulas for enterprises that use their networks inefficiently (Cooper et al., 2011). Benchmarking formulas presented in the table indicate the optimal technologies related to the technology (network usage composition) of the effective enterprises. The research indicates that F1 peers are F2 and F19. F1 must follow 83.3% of the total network utilization of F2. Furthermore, it must also follow 83.3% of total network inputs of F19 to become efficient. F3 peers are F12, F2, F25 and F19. It must follow 14.7% of F12 network technology (usage of all network inputs), 16.7% of F2 technology, 24% of F25 technology and 85.3% of F19 technology to become efficient. To become efficient, F5 needs to imitate F12 (in 55.6%), F19 (in 83.3%) and F25 (in 27.8%). F8 must follow 12.1% of F12, 39.4% of F4 and 100% of F19. F13 must follow 11.4% of F25, 30.4% of F12, 12% of F7, 4.4% of F2, 2.2% of F4, 37.8% of F11 and 22.5% of F19. F14 must follow 57.1% of F2, 12.9% of F7, 10% of F25 and 67.1% of F19. F15 must follow 23.1% of F12, 19.2% of F2, 30.8% of F25 and 138.5% of F19. F16 must follow 21.8% of F2, 4.8% of F4, 19.4% of F25 and 61.3% of F19. F17 must follow 18.4% of F4, 18.4% of F11, 36.8% of F2, 92.1% of F19 and 46.1% of F25. F18 must follow 123% of F2 and 83.3% of F19. F20 must follow 10.5% of F4, 26.3% of F25, 10.5% of F11m 52.6% of F19 and 21.1% of F2. F23 must follow 7.7% of F25, 38.5% of F19 and 15.4% of F12. F24 must follow 3.7% of F25, 7.5% of F12, 33.7% of F2 and 52.5% of F19. F26 must follow 36.1% of F11, 26.9% of F25, 22.8% of F4, 8.9% of F2 and 72.2% of F19. F27 must follow 36.2% of F25, 68.8% of F2 and 72.5% of F19. F28 must follow 30.4% of F19, 25.2% of F4, 0.3% of F11, 11.5% of F2, 14% of F10 and 25.7 of F25. F29 must follow 46.2% of F2, 46.2% of F25 and 107.7% of F19. F30 must follow 42.9% of F2, 42.9% of F25 and 85.7 of F19.

An exemplary, detailed, calculation of inputs in the optimal technology for F24, with the lowest efficiency, contains Appendix Table 2.

The data indicates that the optimal technology for F24, modeled on the technologies of enterprises with the highest relative efficiency of entrepreneurial networks, is determined by the following lambda weights: 0.037 of F25, 0.075 of F12, 0.337 of F2 and 0.525 of F19. This means that it is possible to determine the optimal technology for F25 and it consists of 3.7% of the technology used by F25, 7.7% of the technology used by F12, 33.7% of the technology used by F2 and 52.5% of the technology used by F19. The calculations show that the optimal technology recommended for F24 should use much fewer inputs than the amount actually used. The optimal level of usage of individual subnets should be between 20% and 36% of the current utilization. The F24 company can therefore reduce the intensity of contacts with people from individual networks while maintaining the current information effects. In practice, this can lead to time saving and its possible use for other activities that are crucial for increasing overall performance.

Finally, peer count was calculated, showing the number of times a peer firm was being used as the reference unit. The results of peer count are shown in Table 2.

Table 2. Peer count summary

Firm ID	Peer count	Firm ID	Peer count	Firm ID	Peer count
F1	0	F11	5	F21	0
F2	15	F12	7	F22	0
F3	0	F13	0	F23	0
F4	7	F14	0	F24	0
F5	0	F15	0	F25	15
F6	0	F16	0	F26	0
F7	2	F17	0	F27	0
F8	0	F18	0	F28	0
F9	0	F19	19	F29	0
F10	1	F20	0	F30	0

Examining number of times each firm is a peer for another, it may be concluded that F19 has been used as a peer 19 times, while F2 and F25 have been used 15 times. F4, F7, F10, F11, F12 have been used 7, 2, 1, 5 and 7 times respectively. F2, F4, F7, F10, F11, F12, F19 and F25 are models for inefficient units. The special dominance of the F19 company as a model entity can be noticed here. As pinpointed by Guzik (2009), such dominance of one benchmark is very rare. This indicates that the F19 enterprise, and in particular the use of entrepreneurial networks by this entity, should be subject to special analysis.

6. Conclusions

The study emphasized the utilitarian use of the DEA method to measure and assess the information efficiency of entrepreneurial networks. The study also provided a novel perspective of the analysis of information effects of entrepreneurial networks of manufacturing firms. This study proves that entrepreneurial networks influence the importance of information gathered for the purposes of management of manufacturing firms but the efficiency of gathering the information may vary. This study also incorporates DEA method analysis into social network research. The obtained results have not been compared with the results obtained by other authors due to their innovative nature and the lack of research results predisposed to discussion.

The primary conclusions arising from the study constitute both the contribution to the development of the discipline of management and some practical guidelines for managers-entrepreneurs since it should be pinpointed that the recognition of the efficiency of gathering information from social networks can be the basis for the conscious creation of the effectiveness of acquiring information from social networks, and thus the conscious use of social networks in economic activity.

It is worth concluding that the research was conducted on a non-representative research sample, and these are pilot studies. Therefore, the results may refer only to the research sample and the generalization could be possible only after conducting further examinations on the representative sample. It should be borne in mind that all analyzes using DEA always refer to specific groups of entities – decision-making units - and their results constitute an individual basis for analyzes and assessments. This feature can be considered a specific limitation relating to the conducted research, but it is impossible to eliminate due to the fact that it is an inherent feature of the DEA method used.

The DEA method can be used as a practical tool for evaluating the efficiency of using social networks as a source of information for enterprises, constituting one of the stages of the comprehensive analysis of the functioning of the surveyed entities. Due to the use of variables describing the inputs (use of social networks) and the information effects of these inputs, the efficiency indicator was developed, allowing for the comprehensive assessment of the functioning of the group of surveyed production enterprises. The obtained results lead to an interest in the way of using entrepreneurial networks of effective enterprises, and particularly those among them that most often constitute a model for ineffective enterprises. The companies occupying the top of the ranking were characterized by the appropriate use of network resources, necessary to achieve information objectives. However, it is worth remembering that the functioning of the surveyed entities is also affected by external variables that may affect the level of their efficiency in obtaining information from the network. The calculations made it possible to indicate the effective entities, which should be followed by enterprises with a lower efficiency indicator, and to determine how much the expenditure of ineffective entities should be changed to achieve efficiency. Having in mind the practical use by managers, it should be pinpointed that the effects of improvements introduced in enterprises based on the DEA results can be analyzed exclusively within the framework of the same group of enterprises. Therefore, to state whether the changes implemented on the basis of the results of such an analysis has contributed to an increase in information efficiency, it is necessary to compare exactly the same entities. There is no possibility of making comparisons between groups of different enterprises.

Among the proposals for further research, it is possible to indicate the extension of the conducted to the analysis of the efficiency of production companies against the background of enterprises from various sectors of the economy (e.g. representing a structure adequate to the structure of the national economy of Poland) or a two-stage analysis taking into account, first, the implementation of information effects in terms of resources, and then in terms of opportunities. The future direction of research may also be the comparison of efficiency between enterprises from different countries. Such research would allow for comparing the information efficiency of entrepreneurial networks in a broader perspective, not only for production companies, but it would enable generating certain generalizations. However, it should be remembered that DEA allows for comparing efficiency in a specific analysed group and the objective of its application is not to generate generalizations for the entire population. The presented approach is not, therefore, aimed at generalizing the results but presenting the possibilities of the application of DEA in specific conditions.

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Appendix

Table 1. Firm peers and peer weights

Firm ID	Peer firm ID and weight						
F1	0.833*F2	0.833*F19	-	-	-	-	-
F2	1.000	-	-	-	-	-	-
F3	0.147*F12	0.167*F2	0.240*F25	0.853*F19			
F4	1.000	-	-	-	-	-	-
F5	0.556*F12	0.833*F19	0.278*F25	-	-	-	-
F6	1.000	-	-	-	-	-	-
F7	1.000	-	-	-	-	-	-
F8	0.121*F12	0.394*F4	1.000*F19				
F9	1.000	-	-	-	-	-	-
F10	1.000	-	-	-	-	-	-
F11	1.000	-	-	-	-	-	-
F12	1.000	-	-	-	-	-	-
F13	0.114*F25	0.304*F12	0.120*F7	0.044*F2	0.022*F4	0.378*F11	0.225*F19
F14	0.571*F2	0.129*F7	0.100*F25	0.671*F19	-	-	-
F15	0.231*F12	0.192*F2	0.308*F25	1.385*F19	-	-	-
F16	0.218*F2	0.048*F4	0.194*F25	0.613*F19	-	-	-
F17	0.184*F4	0.184*F11	0.368*F2	0.921*F19	0.461*F25	-	-
F18	1.250*F2	0.833*F19	-	-	-	-	-
F19	1.000	-	-	-	-	-	-
F20	0.105*F4	0.263*F25	0.105*F11	0.526*F19	0.211*F2		
F21	1.000	-	-	-	-	-	-

F22	1.000	-	-	-	-	-	-
F23	0.077*F25	0.385*F19	0.154*F12	-	-	-	-
F24	0.037*F25	0.075*F12	0.337*F2	0.525*F19	-	-	-
F25	1.000	-	-	-	-	-	-
F26	0.361*F11	0.269*F25	0.228*F4	0.089*F2	0.722*F19	-	-
F27	0.362*F25	0.688*F2	0.725*F19	-	-	-	-
F28	0.304*F19	0.252*F4	0.003*F11	0.115*F2	0.140*F10	0.257*F25	-
F29	0.462*F2	0.462*F25	1.077*F19	-	-	-	-
F30	0.429*F2	0.429*F25	0.857*F19	-	-	-	-

Table 2. Calculation of optimal technology for F24

	Subnetwork ID							
	C_KL_ZL	C_DO_US	C_PB_NKON	C_PB_KON	C_ADM	C_WSP_BIZ	C_EX_WSP	C_DOSW
Technology F25	7	6	6	6	6	6	5	7
Coefficient for technology F25 0.037*F25	0.259	0.222	0.222	0.222	0.222	0.222	0.185	0.259
Technology F12	4	4	1	0	4	4	3	4
Coefficient for technology F12 0.075*F12	0.3	0.3	0.075	0	0.3	0.3	0.225	0.3
Technology F2	2	2	2	0	1	1	1	1
Coefficient for technology F2 0.337*F2	0.674	0.674	0.674	0	0.337	0.337	0.337	0.337
Technology F19	1	1	3	3	1	1	1	1
Coefficient for technology F19 0.525*F19	0.525	0.525	1.575	1.575	0.525	0.525	0.525	0.525
Optimal technology F24	1.758	1.721	2.546	1.797	1.384	1.384	1.272	1.421
Actual technology (empirical) F24	5	7	7	5	5	6	6	7
Optimal value as % of empirical value	35%	25%	36%	36%	28%	23%	21%	20%

使用数据包络分析测量制造企业的创业网络绩效

關鍵詞
社交网络
创业网络
数据包络分（DEA）
信息

摘要
本文的目的是分析使用数据包络分析（DEA）方法（一种非参数方法）测量制造企业的企业家网络绩效的可能性，从而可以评估制造企业中企业家社交网络的有效性。 产生信息效应的背景。 该研究利用从 30 家随机选择的波兰企业获得的数据来探讨创业网络的水平及其信息效应（作为绩效指标）。 研究局限性如下：研究仅限于波兰随机选择的实体，结果不能推广。 本文的独创性/价值在于，这项研究既对管理学科的发展做出了贡献，又为管理者企业家提供了实用指南，因为应该指出的是，认识到从企业中收集信息的效率。 社交网络可以成为有意识地创造从社交网络获取信息的有效性的基础，从而成为有意识地在经济活动中使用社交网络的基础。 所呈现结果的新颖性在于填补了空白，同时考虑到使用 DEA 方法评估创业网络绩效。