Analysis of the Effectiveness of Technological KM Tools in the SME Sector Using the DEA Model

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Abstract: Knowledge management has emerged over the past decade as one of the key issues at the heart of modern organisations. The Industrial Age has been replaced by the Knowledge Age. It is a time when strategic management of knowledge and resources is a critical success factor for the organizations. Good Knowledge Management (KM) practices can equip the organizations to be more innovative and provide better integration and sharing of knowledge, which is the basis for starting new organizations or revitalizing mature organizations. The issue of knowledge management is primarily considered in the context of large organisations. In contrast, relatively little attention has been paid in the literature to the specifics of knowledge management in small and medium-sized enterprises. Small and Medium Enterprises (SMEs), the backbone of the economy, significantly benefit from KM practices. The operation of modern organizations in the SME sector requires constant adaptation of management methods and development strategies to new economic conditions. This is particularly important in the process of digital transformation, which has been making significant transformations in the area of economy for a few years now. This also applies to the issue of knowledge management in business organizations, which can be considered in the area of organizational structures, business processes, personnel, organizational culture, but also ICT technologies supporting this management. Advanced ICT solutions for knowledge management, understood as the systematic and organized use of its resources to improve the functioning of the organization, implemented within the framework of process orientation, come to the rescue. The article implies a research method based on a non-parametric DEA model, in particular CRS, identifying inputs and outputs and used to study the effectiveness of using technological tools for knowledge management in enterprises operating on the Polish SME market. In the literature, there is no use of the DEA method to study the effectiveness of technological tools for knowledge management in companies in the SME sector. The research objective of the article is to analyse the effectiveness of the use of technological tools for knowledge management in enterprises operating on the Polish SME market. The study was carried out using the non-parametric DEA method, which is based on a two-factor concept - technical efficiency (TE), meaning the ability of a company to produce maximum output (effects) for a given level of inputs, and allocative efficiency (AE), which in turn means that a company can use inputs in optimal proportion to individual prices (input costs). After analysing all possible inputs and effects, it was assumed that the following factors have a primary impact on the individual efficiency of technological KM in the SME sector: sales revenue, number of computer workstations, net profit included in effects, and fixed assets in the form of IT equipment, intangible assets in the form of software and the number of employees using technological KM tools included in inputs. Data for the survey was obtained using the CATI method among 600 randomly selected SMEs operating on the Polish market.

Keywords: Knowledge Management KM, SME, Technological Tools KM, DEA Model

1. Introduction to Technological Tools KM in SME Enterprises

The micro, small and medium-sized enterprise (SME) sector plays an important role in all economies around the world (Barroso, Ferreira, Meidute-Kavaliauskiene, Banaitiene, Falcao, Rosa, 2019). In Poland, there are 2.4 million non-financial enterprises, defined as active enterprises, of which 99.8% are enterprises included in the SME group (according to data for 2021 of the Polish Central Statistical Office (GUS). In recent years, entrepreneurship in Poland has been characterised by three distinct trends. Firstly, over the last few years it can be seen that the entrepreneurship of Poles is not waning. The number of enterprises is growing dynamically. Secondly, the quality of Polish entrepreneurship is improving. Polish companies as a group are contributing more and more to social welfare. The data show that they produce an increasing proportion of Polish GDP. The average company is growing steadily in economic terms. Its productivity, as measured by revenue, added value and production, is increasing. Trends also point to an improvement in the structure of companies from the point of view of legal forms. The share of companies as legal entities is increasing and that of physical persons is decreasing. Thirdly, the openness of entrepreneurs and their orientation towards growth is increasing. Companies, although still too seldom, are internationalising more and more - the proportion of exporters and the average value of exports are systematically increasing, as well as the use of the advantages of an online presence. Polish companies are also investing more and more and developing and implementing innovations, although the scale of development activities is still not high.

In the most general manner, knowledge management (Pritchard, 2010) is defined as a management method, the basic aim of which is the unconventional development of competitive advantage (Glabiszewski, Sudolska, 2009) by contemporary operating enterprises, including non-profit organisations (Perechuda, 2005). The great supporters of the knowledge management concept are T.H. Davenport and S.C. Völpel, who pointed out,

however, that knowledge management primarily plays an important role in improving methods of creating new knowledge, and then in its proper dissemination and use (Davenport, Völpel, 2001). Another definition of knowledge management is proposed by P. Murray and A. Myers, who presented it as a sum of processes enabling the creation, dissemination and use of knowledge, in order to achieve the goals set by the organisation (Ahmad, JianMing, Rafi, 2019) (Strojny, 2000). Knowledge management was also characterised by D.J. Skyrme, who described it as a precise and systematic management of knowledge resources and the related processes of creating, collecting, disseminating and using knowledge to ensure the organisation's proper functioning (Skyrme, 1999). Providing the right conditions to support the implementation of such a system into an organisation depends largely on a number of factors, among which the following stand out: adequate resources, the right management system and organisational structure (Liczmańska-Kopcewicz, 2017), appropriate organisational culture and communication, and a properly designed organisational strategy. For this reason, knowledge is still a resource that, when properly used, can contribute to a given company's competitive advantage in the market (Centobelli, Cerchione, Esposito, 2017) (Bamel, Pereira, Bamel, Cappiello 2021).

Knowledge in small and medium-sized enterprises cannot be created according to the same procedures as in large organisations, which results from the small potential in terms of human resources, capital, technology and development. The knowledge management system should prevent the loss of knowledge possessed by the organisation, but should also create knowledge within the existing resources. This system must be an attempt at a holistic approach to organisational phenomena and processes. The management of an organisation must independently create a knowledge management system in its organisation, adapted to the specifics of the enterprise and its human and financial capabilities. An attempt to comprehensively implement knowledge management in an SME must, taking into account the scale, cover such areas as the IT system, organisational culture and employee management. The functioning of modern SME organisations requires constant adaptation of management methods and development strategies to new business conditions. This is particularly important in the process of digital transformation, which has been making significant transformations in the area of the economy for some years now. This also applies to the issue of knowledge management in business organisations, which can be considered in the area of organisational structures, business processes, personnel, organisational culture, but also in the area of ICT supporting this management. This means that under conditions of extreme competitiveness as part of the digital transformation, the management methods used so far, which are aimed often aimed solely at ensuring stability and predictability. With help comes advanced ICT solutions for knowledge management (Preuss, Cordoba-Pachon ,2009), understood as systematic and knowledge, understood as a systematic and organised use of its resources to improve the functioning of the organisation, realised within the framework of the process orientation by (Unold, 2015):

- knowledge location and acquisition,
- collecting knowledge and processing it,
- its enrichment and sharing.

The knowledge management system consists of the following elements:

- knowledge management strategy - indicating priorities for action, defining the role of knowledge management in the process of achieving the organisation's strategic objectives,
- people and organisational culture - the willingness of employees to share knowledge, supported by organisational culture,
- business processes - the process orientation of the organisation to effectively collect, share and retrieve knowledge,
- information and communication technologies - these provide users with information and communication technologies - these provide users with effective collection, processing and sharing of data (transformed into information and further into knowledge).

In practical terms, this means the need for modern ICT solutions for knowledge management, enabling the support of business processes business processes as part of gaining and strengthening competitive capabilities. During evolution of the information society towards a knowledge society it boils down to treating modern enterprises as intelligent organisations intelligent. An intelligent organisation is one that bases its operating philosophy on the management of knowledge (Waltz, 2003). The term became widespread in the 1990s. due to the development of ICT, the dynamically changing economic environment and increased market competitiveness. An intelligent organisation is an organisation learning organisation, which has the ability to create, acquire, organise and share knowledge, use it to improve the efficiency of its operations and sharing it, using it to improve operational effectiveness and increase competitiveness in the global market. The idea of

such an organisation is based on a systemic approach to the organisation, i.e. treating it as a complex organism based on existing structures and implemented processes with particular emphasis on the role of knowledge. Attributes of smart organisations include (Beckford, 2016), (Grösser, Zeier, 2012), (Schwaninger, 2010):

- speed and flexibility of action,
- the ability to observe the environment,
- the ability to diagnose market signals early and respond to changes in the environment,
- the ability to quickly implement new knowledge-based solutions and thereby achieve the economic benefits.

The classification of tools supporting knowledge management due to the ambiguity of the terms causes many difficulties. In fact, the very definition of a "technological tools" in the knowledge management process is difficult to classify and raises many questions. Both the tools themselves and the functionalities they possess are not easy to classify. Many times the nomenclature of tools overlaps with the nomenclature of functionalities, and the functionality of a tool dedicated to one process is provided by another tool. In addition, technological trends are moving towards flexible tool design tools allowing a given tool to be used for multiple purposes depending on the depending on the concept of the organisation in question. Mechanisms to support knowledge management are based on three core technologies: database, network and web technology. Database technology - understood as the technology associated with the physical and logical structuring and storage of data. From a technological point of view, it is based database mechanisms and programming language systems. Network technology - understood as a set of network connections, mechanisms responsible for the coordination of all processes related to data exchange. This technology consists of two layers: a first hardware layer realised through. The first layer is hardware, implemented by servers, network connections and a number of tools related to synchronisation of the network synchronisation, and the second layer represented by software designed to implement the above-mentioned activities. Web technology - understood as a technology combining database technology. Web technology is implemented through websites and any mechanisms related to the representation of data on websites. The Websites present data, information, knowledge from various sources, often accumulated in many databases and files, sources, which are often combined in multiple databases and files. By means of web technology on websites equipped with the appropriate applications the web technology provides tools to share information and knowledge. Web technology provides tools for a range of knowledge management processes, such as: knowledge sharing between experts, discussion forums experts, discussion forums, corporate portals and many others. However, it is important to remember that the foundations of web technology most perceived by users are database technology and network technology.

Each of the aforementioned technologies enables the implementation of multiple knowledge management functionalities. Many times, knowledge management tools are based on all three technologies.

2. Methodology - Characteristics of an Efficiency Study Using the DEA Model

No studies of the effectiveness of using technological tools for knowledge management in the SME sector were found in the literature. However, a combination of DEA and KM approaches has been noted. Kuah and Wong used a two-level DEA model to measure the performance of Malaysian universities in relation to KM factors (Kuah, Wong, 2013) while Shirouyehzad, Rafiee, Berjis considered KM and safety management criteria as inputs and customer satisfaction and accident rates as outputs of a DEA model to evaluate the performance of 12 automotive companies in Esfahan (Shirouyehzad, Rafiee, Berjis, 2017). However, some studies can be found in which DEA has been applied to select, improve or evaluate Six Sigma projects. In the literature we also find the use of the hybrid DEA technique for the selection of six sigma projects (Hadi-Vencheh, Yousefi, 2018) (Wen, An, Xu, Chen, 2018). In the literature, we will also encounter the PCA-DEA approach to investigate the impact of the six sigma extension on key work characteristics in the automotive industry (Azadeh, Nasirian, Salehi, Kouzehchi, 2017). Therefore, the implication of the DEA method to study the effectiveness of technological tools for knowledge management in the SME sector is an important contribution.

Efficiency analysis using the non-parametric DEA method is based on a two-factor concept, with technical efficiency (TE) (Lang, Welzel, 1996), meaning the firm's capability to produce maximum output (effects) at a given level of inputs, and al-locative efficiency (AE) (Rogowski, 2008) meaning that the enterprise can use inputs in optimal proportion to individual prices (input costs). It is often used to study efficiency (Tavares 2002). The combination of TE and AE gives total economic efficiency (EE) (Sikora, Kulczycki, 2009). In the case of the concept of technical efficiency introduced by Farrell, the difference between the stated level of production of

the enterprise and the limit of its actual production capacity is taken into account (Welzel, 1996). Deviation from an efficient production plan means that the pro-duction of the outputs of a combination of inputs (the results obtained) could have been achieved with less input, which means a waste of resources (Welzel, Lang, 2005). The technical inefficiency caused by this fact increases in proportion to the distance from the effective production limit (Sheldon,1994). An important element in the study of corporate efficiency is the evaluation of economies of scale. Failure to take advantage of existing economies of scale results in efficiency losses for the enterprise (Wielgórka, 2008). From a general point of view, economies of scale illustrate the response of the level of outputs to a proportional increase in inputs. In the case of economies of scale, the quantity of outputs produced increases relatively faster than the level of inputs, which means that unit costs fall. In the opposite case, i.e., declining economies of scale (diseconomies of scale), unit costs rise as the level of outputs rises. In the situation of fixed scale effects, despite the increase in the number of outputs, the cost of producing one unit of outputs remains unchanged (Gospodarowicz, 2000). The DEA method makes it possible to determine the presence or absence of scale effects. Proponents of non-parametric methods, including the authors of the DEA method, are based on the concept of productivity, defining a measure of productivity as the quotient of a single output and a single input. By having one input (x) and one output (y), one can obtain an efficiency curve. This curve contains a set of objects with inputs (x) and outputs (y) that achieved the maximum possible outcomes, given a specific level of inputs. All combinations of inputs and technologically possible outputs lie between the OX axis and the efficiency curve (production frontier), i.e. the input-output relationship curve. DEA was developed specifically to over-come the drawbacks of parametric analyses, by evaluating efficiency based only on avail-able data on the magnitude of inputs and outputs without having to determine their functional relationship, which is very difficult when the number of factors is large. The units under evaluation in DEA are called decision-making units (DMUs) and a DMU is considered to be efficient when no other DMU can produce more outputs using an equal or lower amount of inputs (Ebrahimnejad, Tavana, Nasseri, Gholami, 2019) (Maleki, Ebrahimnejad, Kazemi, 2019). What makes the difference in DEA models is the concept of RTS. In the case of constant RTS, the CRS model will be used. Meanwhile, in terms of variable RTS, the BCC model should be used. Since recognizing the RTS is a long-term procedure, there is a need to collect data from different periods and analyze them (Amani, Valami, Ebrahimnejad, 2018), and regarding the limitations on data collection (we only were allowed to collect data in one period) we were not able to determine the RTS. Objects are considered technically efficient if they are on the efficiency curve, while those that are below the efficiency curve are technically inefficient. Decision making units (DMUs) are the objects of analysis in the DEA method. The main focus of the analysis is the efficiency with which a DMU transforms inputs into outputs. The relationship be-tween the efficiency of a given object and its maximum efficiency achievable under given technological conditions is taken as a measure of technical efficiency. Depending on model orientation, either input-oriented technical efficiency or output-oriented technical efficiency is calculated. The first point in evaluating efficiency using DEA is to define the ap-propriate technology that provides a baseline for the measurements to be made. For this purpose, a set of n decision making units that produce s outputs using m inputs is considered. For each DMU, the input and effect vectors are labelled and, respectively, with x > 0 and y > 0, which means that each decision making unit is assumed to have at least one input and one effect. The production technology thus defined:

$$T = \{(X,Y) : X \geq \sum_{j=1}^{n} \lambda j Xj, Y \leq \sum_{j=1}^{n} \lambda j Xj, \lambda j \geq 0\}$$

is subject to four fundamental assumptions [72]:

1) convexity - when (Xj, Yj) ε T, j - 1, ..., n, and λj ≥ 0 are non-negative scalars such that:

$$\sum_{j=1}^{n} \lambda j = 1$$

, then

$$(\sum_{j=1}^{n} \lambda_1 X_1, \sum_{j=1}^{n} \lambda j Yj) \in T$$

2) inefficiency

- when (X, Y) ε T and then

- when (X, Y) ε T and , then

3) constant economies of scale

- when $(X,Y) \in T$ (kX, kY) ε T for each k > 0

4) of minimum extrapolation, i.e. the condition that the technology must contain all possessed combinations of inputs and outputs.

The development of alternative DEA models has changed some of the assumptions.

In particular, the assumption of constant economies of scale was questioned in the further development of the methodology. The primary model of the DEA method is a non-linear (index) form, containing the weighted sums of inputs x and outputs y for a given DMU. The task of the model is to maximize this quotient assuming that it cannot be greater than 1 for any other decision making unit:

$$\max h_o = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=0}^{m} v_1 x_{1o}} \qquad ST: \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v, xi_j}$$

j = l, …, n; ur,; vi ≥ 0, r = 1, …, s; i l, …, m

After transformations, the normal linear form is obtained:

max Zo

$$ST: -\sum_{j=1}^{n} Y_{rj}\lambda_j + Y_{r0}Z_0 \le 0$$

$$\sum_{j=1}^{n} X_{ij}\lambda_j \le X_{10}$$

$$\lambda j \ge 0$$

r - l, …, s; i - l, …, m; j - l, …, n

Subsequent modifications result in a form of the basic input-oriented CRS model:

$$\min \Theta_0$$

$$ST: \sum_{j=1}^{n} x_{ij}\lambda_j \ge y_{r0}$$

$$X_{10}\Theta_0 - \sum_{j-1}^{n} x_{ij}\lambda_j \ge 0$$

$$\lambda j \ge 0, j = 1,\ldots,n$$

This model is designed to minimize the input demand up to the efficiency limit so that an input efficiency ratio is obtained. When the value of the coefficient is = l, the DMU is fully effective, which is expressed by the 100% transformation of its inputs into outputs. A proportional reduction of inputs is not an option in this case as it would imply a simultaneous loss of efficiency. A score lower than one suggests that the unit is inefficient, as it wastes (1-)*100% of inputs.

In economic terms, the technical efficiency (TE) of the enterprise, calculated by solving the CRS model refers to the situation of the presence of constant economies of scale. This means that a proportional increase in inputs entails a proportional increase in outputs. Companies aim to determine the volume of production at which costs reach the lowest possible level. In the long run, the efficiency curve will approach the shape of the curve with constant economies of scale.

3. Research on the Effectiveness of Technological KM Tools in the SME Sector Using the DEA Model

The research problem is the implication of the DEA method for assessing the effectiveness of the use of technological tools for knowledge management in companies operating on the Polish SME market. The implementation of this non-parametric method requires the definition of inputs and effects and then subjecting these factors to efficiency analysis. After analysing all possible inputs and effects, it was assumed that the following factors have a primary impact on the individual efficiency of technological KM in the SME sector: sales revenue, number of computer workstations, net profit counted as effects, and fixed assets in terms of IT equipment, intangible assets in terms of software and number of employed people using KM technological tools counted as inputs.

A comprehensive survey based on an interview questionnaire, classified as quantitative research, was conducted in 2022. Interviews were conducted with owners, co-owners and persons responsible for management in the segment of SME companies in Poland, from various industries. The survey involved 600 randomly selected SME companies operating on the Polish market, of which 40% were micro-enterprises employing up to 9 people, 30% small entrepreneurs employing up to 49 people and 30% medium-sized entrepreneurs employing up to 249 people. The structure of the survey was weighted to the structure of companies in Poland according to the regon database operator (Central Statistical Office). The research sample prepared in this way enables data analysis at the level of the entire SME population in Poland. The survey was conducted using the CATI (Computer Assisted Telephone Interview) method in 2022. This is one of the methods of collecting information in quantitative research.

Table 1: CRS TE performance measure statistics in the analysis of the effectiveness of technological KM tools in the SME sector from 2017 to 2021

Statistics CRS TE	2017	2018	2019	2020	2021
Standard deviation	0,17	0,19	0,17	0,19	0,20
Minimum value	0,20	0,19	0,23	0,24	0,22
Number of effective SMEs	228	246	258	288	294
Number of ineffective SMEs	372	354	342	312	306
% Effective SMEs	38%	41%	43%	48%	49%

The CATI survey was conducted using a special programme that assisted the caller to the respondent throughout the interview. The interview questionnaire consisted of a core part (essential questions) and a metric (classification questions). The core part of the questionnaire was designed to obtain information about knowledge management in SMEs. The questionnaire contained information about the surveyed enterprises: number of employees, revenue, balance sheet total, legal form, type of activity according to PKD, period of activity, official position of the person completing the questionnaire. One of the stages of the comprehensive study was to assess the effectiveness of the use of technological tools for knowledge management in enterprises operating on the Polish SME market using a non-parametric DEA model, in particular the CRS model assuming the presence of fixed economies of scale.

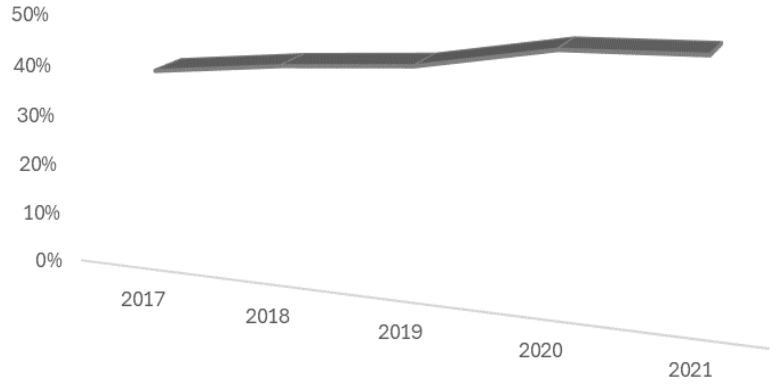

Figure 1: Level of SMEs effectively using technology tools for knowledge management 2017-2021

Measures derived from the estimation of input-oriented models will determine the ratio of the actual output of the SME to that which the SME should have had if it had effectively used the same amount of inputs. Over the period studied, the total number of efficient SMEs effectively using technological KM tools is increasing, which is a positive development (Figure 1).

By estimating the CRS model, technical efficiency (TE) can be calculated, which determines the possible amount of inputs that can be used under given technological conditions to produce at least the same amount of products. In 2021, only 49% of SMEs were effectively using technological KM tools (Figure 2).

In particular, the number of effective enterprises (i.e. effectively using technological tools for knowledge management) increased in the group of small and medium-sized enterprises reaching 52% and 63% of the total surveyed entities, respectively. In the microenterprise group, the number of effective entities represented only 32% in 2021. It should be inferred that larger companies in the SME group make more effective use of technological tools for knowledge management.

4. Conclusion

The research conducted investigated the implications of the non-parametric DEA method for quantifying the effectiveness of the use of technological tools for knowledge management in the SME sector.

The estimation of the DEA model in the area of efficiency coefficients that each SME could achieve ranged from 0 to 1. A coefficient value equal to 1 indicates an efficient SME, while an efficiency coefficient value lower than 1 indicates that the SME in question has room for improvement in the input-output ratio of technological KM tools. During the 2017-2021 period under review, it is important to note an increasing trend in the number of effective SMEs using technological KM tools. The increase in the number of effective SMEs is mainly related to the growing role and awareness of knowledge utilisation in SMEs. However, the lowest level of effective use of technological tools for knowledge management was noted in the microenterprise group. Larger enterprises in the SME group make more effective use of technological tools for knowledge management.

The effective use of technological knowledge management tools in SME companies plays a very important role today. It facilitates and streamlines organisational processes, supports business processes, shapes organisational culture by changing rules, forms, habits of cooperation and communication. Digital solutions are also helpful in building relationships with customers, enabling feedback on the quality of service or purchase preferences. There is huge potential in the SME sector, especially in the group of micro-enterprises which, lacking strong financial backing, are unable to meet the demands of the market. Therefore, it is important to build a financial support programme for SMEs, especially micro-enterprises, to increase the use of technological tools for knowledge management, which will improve the competitive position of this sector. The implication of the DEA method will allow it to be further used in subsequent studies on knowledge management in the SME sector.

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