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The potential of intellectual capital as a source of competitive advantage for banks using CART classification trees

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Abstract

Motivation: Most of the available analyzes on building banks' competitiveness were based on typical financial ratios. The challenge for every modern bank is not just understanding the meaning of intellectual capital, but defining its elements and determining measures that enable its effective management, leading to the improvement and maintenance of a strong competitive position. Empirical research concerning the competitiveness of banks in Poland is increasingly focused not only on efficiency and financial indicators but more often on emphasizing the significance of the components describing the IC subsystems, which include: service quality, bank reputation, customer confidence in the financial service of a given bank and the attractiveness and comprehensiveness of its offer as significant determinants of the overall assessment of a given entity.

Aim: The aim of the article is to systematize the definition of a bank's intellectual capital and to indicate its role in building a bank's long-term competitive position using multidimensional statistical analysis — classification tree (CART method).

Results: The conducted analysis will allow to find rules (based on diagnostic indicators) classifying banks into separate groups (A, B, C). This will lead to the conclusion which indicators from the economic (EC) and intellectual (IC) capital layers have the greatest impact on the competitiveness of banks (2009–2020).

Keywords: *intellectual capital; competitiveness; bank*

JEL: G21; O34 ; J24; M21

1. Introduction

The banking sector has always been considered as a specific area of the economy, due to the fact that, exposed to too high a level of competition, it may increase the risk for other sectors or cause a crisis. For this reason, banks were subject to strong regulations relating to interest rates, geographic scope and structure of the activity in question. The specificity of the sector is also determined by the presence of the central bank as the lender of last resort or guaranteed deposit schemes. Banks, as institutions of public trust, cannot afford to damage the image and lead to the collapse of weaker units. This is because it lowers the trust of stakeholders and destabilizes the financial sector. Although, of course, a certain exception, and at the same time proof (of these claims), is the financial crisis, including the collapse of Lehman Brothers.

In the literature on the competitiveness of banks, there has recently been a noticeable tendency to appreciate, emphasize the importance, and even focus individual groups of researchers on the intangible assets of the bank. However, this does not change the fact that these studies ultimately still present the results of research referring primarily to the financial condition, regulatory policy, interest rates, the credit and deposit market, or the consolidation of the banking sector. Non-financial factors of building competitiveness are rather mentioned, discussed, and rarely taken into account in research. The importance of intellectual capital in the development of modern enterprises (including banks) is widely described. The prepared research on their condition usually takes into account selected entities on individual markets. As far as the intellectual capital of banks is concerned, research has so far focused only on its selected elements and their impact on the competitive position. However, there are no comprehensive studies combining traditional indicators of profitability and efficiency of economic capital (EC) and studies that take into account the state, strength of influence and potential of intellectual capital. Intellectual capital (IC) is hidden in the relationships and skills and knowledge of employees, cooperators, customers, competitors or shareholders. It has a significant impact on the creation of a relational mechanism regarding the organizational sphere, innovation and contacts with the external and internal environment. The network of organizational, pro-innovation and institutional relations is the foundation of the ability to create socio-economic values, which are the basis for sustainable development.

The author of the article will make a critical analysis of the literature defining the concept of banks' intellectual capital, as well as a review of empirical research relating to the impact of banks' intellectual capital on their competitiveness. The author wants to point out that the concept of intellectual capital, as well as the competitiveness of banks, does not have a uniform, standardized definition, as well as measurement methods. The article may be the beginning

of a discussion on the validity of using multidimensional methods in the study of intellectual capital and its impact on the competitiveness of banks, and an attempt to unify these concepts. One of the methods of multidimensional statistical analysis will be used — the construction of a classification tree (CART method) using the Statistica 13 program. The method will allow to verify which diagnostic indicators used in the construction of a synthetic measure (competitiveness of 10 banks according to 26 parameters) enabled the assignment of banks to separate groups (A — places 1–3 in the competitiveness ranking of banks, B — places 4–7 in the competitiveness ranking of banks and C — last places in the competitiveness ranking). It should be noted that the classification tree method has been continuously used by researchers since the late 1980s, applying it to various issues (creditworthiness, marketing research, company bankruptcy, automotive market segmentation). The main advantage of the adopted method is that there is no need to know the distribution of explanatory features (indicators) or the analytical form of the relationship between these features and the dependent feature The model can use both quantitative and qualitative features and is not sensitive to missing data, which made it possible to include data that was throughout the research period.

2. Literature review

Competition in the banking sector is desirable due to efficiency and maximization of benefits for customers. However, as indicated, due to the role and functions of the banking sector, there are some characteristics that distinguish it from others. It is important that the banking sector is competitive and efficient, but also stable. This has consequences regarding the principles of development of the sector and the methods of competing of the participating entities. In addition, it indicates the need to look at the strength of competition in the sector (competitive struggle between participants, degree of concentration, strength of individual participants), not only in terms of efficiency indicators, but also in a comprehensive approach, taking into account the long-term ability to be competitive in changing conditions (Anielak-Sobczak, 2022, p. 39).

The high intensity of competition in the banking sector resulted in the development of strategies for building long-term competitiveness, using various methods of competition. The microeconomic approach, which is relatively new in banking, draws attention to the fact that the bank operates on a commercial basis and is willing to constantly monitor the situation on the market (Skawińska, 2002, p. 18). As a consequence, the resource-based approach began to be used to analyze competition in the banking sector. The resource-based approach tries to explain how companies maintain their position in the environment in conditions of strong competition. The theory focuses not only on the company's efficiency and effectiveness components, indicated in earlier theories, but primarily focuses on strategic behavior, rare, impossible to imitate enterprise

resources that are crucial to stand out from the competition (Burton et al., 2015, p. 37).

The resources of an enterprise (here: a bank) are understood very broadly and include both tangible and intangible assets — staff (employee knowledge), their qualifications and motivation to achieve success, organizational culture conducive to development, company reputation, achievements (in the form of ideas, inventions, innovations) and the efficiency of structures and procedures (Hazlina Ahmad et al., 2010, p. 182). Intangible assets are related to the activities by which organizations can collect, use and renew their tangible assets (Hamel & Prahalad, 1993, p. 75). The resource-based strategy emphasizes that introducing innovation helps to achieve a competitive advantage. Success is the result of the involvement of people from the organizations behind the innovation, contextual factors related to its implementation and dissemination, and the benefits of innovation for stakeholders and the company (Teece et al., 1997, p. 5). As an integral area of the resource theory, the knowledge-based approach (Knowledge based view, KBV) should be indicated, in which the most recognized strategic resource of the organization is knowledge. The company builds its competitive advantage and the concept of Organizational Learning, emphasizing the legitimacy of enabling learning to all employees of the organization (learning in the organization), which is conducive to sharing knowledge and developing the organization's ability to learn, and thus determines maintaining an advantage over competitors (Collis & Montgomery, 2009, p. 140).

Nowadays, banks are also perceived as intensively developing enterprises operating in a dynamic environment. Banks' resources are perceived as their strengths, which help to compete effectively with rivals, thanks to the implementation of appropriate strategies for the implementation of the development vision. Banks stand out on the market by acquiring and accumulating unique resources and relationships. The resource theory and concepts of the knowledge-based economy seem to be the most appropriate theoretical basis, adequate to the challenges of building competitiveness by banks in the 21st century. largely from the potential of the bank's intangible resources. They are a source of knowledge necessary to improve the level of customer satisfaction and to provide services and products that distinguish a given bank from its competitors.

The key aim of the article is to emphasize that competitiveness is a concept that goes beyond efficiency. Competitiveness is the ability of an entity (bank) not only to stay on the market, but also to develop thanks to understanding the essence of changes taking place in the environment. The banking sector of the 21st century has changed, as evidenced by, among others, appreciating the microeconomic approach in assessing the competitiveness of participating entities (Herciu & Ogrean, 2019, p. 556).

Banks are also increasingly emphasizing — as a priority — sustainable development issues related to their business activities (such as financial inclusion, financial literacy). In addition, they offer products that promote environmentally friendly activities, including their efforts to mitigate the risk of climate

change. As a consequence, when constructing the pillars of the strategy, banks consciously take into account not only the achievement of financial benefits, but also environmental protection and building good relations between the company and investors, contractors, clients and employees. This means pursuing a sustainable development policy, which in turn is reflected in the emphasis on the use of the bank's intellectual capital (Mollah & Rouf, 2022, p. 85).

Competitiveness is understood as building a long-term competitive position of the bank based on financial assets, but also intangible assets. The authors notice more and more often that it is intangible assets that give the opportunity to use specific environmental conditions to achieve a sustainable competitive advantage. Banks are aware that they must constantly work on improving their competitive position, and taking into account the oligopolistic structure of the banking market and its regulatory specificity, they must largely base this process on the use of internal assets (Bryl, 2020, p. 35).

Financial globalisation, increased competition, computerization and development of communication technologies (ICT), deregulation and regulation are the main drivers of change. New technological and organizational challenges have created a need for new skills This, in turn, made the human factor particularly important. In the works on competitive advantage, it is emphasized that having the appropriate potential of resources and skills that help create added value to today's standard is necessary to create and maintain a competitive advantage (Zaleska & Kondraciuk, 2019, p. 74).Long-term advantage is achieved only by entities whose resources are of strategic importance. Research conducted in various fields of the economy, including financial services, confirms that the economic value of modern enterprises (banks) is less and less dependent on tangible fixed assets, and increasingly on intangible assets (Nazir et al., 2021, p. 6089).

The analysis of previous research shows that researchers mainly focused on identifying structural and institutional factors of banks' competitiveness and assessing the impact of changes on improving efficiency. Each of the researchers emphasized a different aspect of competitiveness, which proves the multidimensional nature of this concept. The presented examples of research on the competitiveness of banks, carried out in various countries, clearly indicate that a full assessment of a bank's competitiveness requires a broader approach. Researchers indicate the sources of competitive advantage, i.e. factors that can guarantee a sustainable competitive position, among which the following are repeated: the quality of services (Piocha & Radlińska, 2008, p. 26), the bank's image and its reputation (Nawaz & Ohlrogge, 2022, p. 4), the implementation of new technologies (Maracine et al., 2020, p. 15), efficiency of business processes (Dirisu et al., 2013, p. 54) product offer (Nothando et al., 2016, p. 32). In their studies, many authors also pay attention to the efficiency and speed of service, availability to customers and employee competences (Klimontowicz & Majewska, 2022, p. 105).

Nowadays, many researchers indicate that the foundation for the development of organizations (including banks) must be not so much the traditional system of organizational dependencies and accumulated tangible assets, but the system of intangible assets as a source of long-term competitiveness. Proven relations, including organizational, innovative and institutional ones, allow for deepening cooperation. The features that make companies stand out from the competition include: innovation, flexibility or the ability to react quickly and effectively to changes in the environment. Success is built by unique and difficult to imitate intangible resources, i.e. intellectual capital (Rehman et al., 2022, p. 113).

IC is defined as knowledge that can be transformed into value, it covers all the elements of the enterprise, existing in addition to cash (Todericiu & Serban, 2015, p. 86). In the simplest terms, IC includes all the knowledge and skills of employees, processes, innovations, technologies, relationships with suppliers and customers, software, reports, publications and databases, patents, trademarks, i.e. what remains after subtracting all tangible values. IC indicates the possessed knowledge, experience, organizational culture, relations with clients and professional skills (Zheng et al., p. 26). It also includes intellectual property, defined as a set of intangible results of human activity, i.e. ideas for innovations that can be attributed to a legal or natural person (Chen et al., 2005, p. 163).

The definition of intellectual capital proposed by other researchers is based solely on human capital as a product of competence and motivation. It does not take into account situational and structural conditions affecting the final shape of IC (Teece et al., 1997, p. 36). According to Wiig (1997, p. 28), intellectual capital is an asset created as a result of intellectual activities, from acquiring new knowledge to creating relationships with people.

When attempting to assess the importance of Intellectual Capital (IC) in building a long-term competitive position, one should remember about the specificity of the entity, business profile, resources, rules for introducing innovations and changes in the range of products/services or the dynamics of target customer groups. Individual components of intangible assets may affect the level of competitive advantage achieved. The brand is of key importance for competitiveness in the long term, as customers identify it with a guarantee of meeting their expectations and needs and with an appropriate human capital management system (Rosińska-Bukowska, 2019, p. 143). An important element is also motivating employees, supporting their creativity and innovation, as well as accumulating the organization's experience, developing knowledge and skills, and building key competences on this foundation. As a consequence of recognizing as justified highlighting the values of IC and emphasizing the important role of knowledge in a modern bank, it was assumed that intellectual capital should be examined as a system composed of three subsystems (Rosińska-Bukowska, 2020, p. 292):

- organizational capital (ORG) — the effectiveness of the organizational system, management principles and organizational structures (in terms of industry); tangible assets, i.e. trademarks, patents, copyrights, databases and IT systems, resulting from the activity of human capital in the bank;
- innovative capital (INN) — creating innovative products, services or solutions as a result of the interaction of human and technological capital;
- institutional capital (INS) — the specificity and model of building relationships with the external and internal environment, allowing the bank to adapt to specific market areas, gaining customer loyalty and building the organization's reputation.

In many studies, the role of human capital is emphasized, but there is no unambiguity as to where it is located. Thus, the assumption (adopted in the article) of the multi-directional and multi-faceted impact of human capital, which means that it penetrates all layers of IC, should be considered reasonable. For example, Bayraktaroglu et al. (2019, p. 467) and Subramaniam and Youndt (2005, p. 54) refer human capital to creativity and innovation employees (i.e. innovative capital), loyalty/dedication and attitudes of employees (i.e. institutional capital), training and education mechanisms that strengthen structures and bind the organizational system through the experience of employees (i.e. organizational capital). In turn, according to the results of research by Isaac et al. (2010, p. 26), the role of human capital is dominant for strengthening institutional capital, which is a combination of significant such as structure, systems, information technology, capabilities, culture, empowerment and service quality.

Bontis and Cabrita (2008, 63) noted the increased emphasis on training employees and improving their motivation are factors that can lead to higher productivity and increased creativity, and thus improve customer satisfaction and build their loyalty. They found that employees, thanks to their professional knowledge, experience and skills, establish better relationships with clients, which contributes to the accumulation of institutional capital (INS). Therefore, the researchers indicated that human capital has a positive and direct impact on IC, appreciating how it affects structures, relationships, innovations, they indicated that the creativity and attitude of employees have a positive impact on structural capital, because employee skills affect the organizational culture, process efficiency and processes innovative.

The findings of Setianto and Sukmana (2016, p. 116) show that banks with higher efficiency of human capital tend to show higher ROA and ROE, which also means an impact on economic capital. The competencies of employees are important in the creation of both tangible and intangible assets, contributing to the continuous creation of knowledge and ideas. These results suggest that to accelerate the development of banking (in Indonesia and Malaysia), stakeholders should focus on developing human capital rather than physical assets. Basically, the financial sector and especially banks need a generation of professional managers who are more customer-centric, tech-savvy, highly skilled,

flexible and agile with versatile skill sets. In the context of globalization, high-class human capital, i.e. the basis for the development of all IC subsystems, has become a necessity, not just a wealth.

The concept of intellectual capital and its impact on competitiveness is the subject of research by many authors. Most of them made an attempt to indicate individual elements of intellectual capital that have the greatest impact on competitiveness. Competitiveness in the studies of many authors is equated with the effectiveness of the bank (efficiency ratios). The research also did not take into account the subsystems of intellectual capital, i.e. organizational, innovative and institutional (the structure adopted in the article). Also, adequate methods of researching their impact, let alone measures, were not recommended.

3. Methods

In the light of the previously discussed changes in the banking market and due to the lack of a uniform indicator defining the competitive position, it is recommended to select indicators adequate to the adopted definition of competitiveness and to analyze competitiveness in dynamic terms, using a set of several measures. It seems reasonable to use a comprehensive multi-criteria assessment. Multi-criteria perception of competitiveness requires the use of appropriately selected measures of economic efficiency, concentration and advanced taxonomic methods. It should be noted that there is currently no universal catalog of measures of the competitiveness of a banking institution. Therefore, in this respect, it is crucial to consider all aspects of their operations, the specificity and characteristics of the entity when examining banks, taking into account effectiveness, market share, mergers and acquisitions, innovation and the adopted strategy (Quan & Emiliano, 2018, p. 135) When constructing measures, it is advisable to take into account as many relevant financial and non-financial data as possible, based on the basic principles of examining the competitiveness of banking institutions (indicated above). In addition, one should remember about the changing business conditions (not only in the banking sector), including the ever-increasing pressure to use knowledge as the basic potential for long-term development. In addition, it should also be emphasized that due to the intangible nature of intellectual capital, there is a difficulty in selecting appropriate tools for its study and measurement. The overwhelming number of available methods describing intellectual capital are qualitative methods, and many elements of intellectual capital are interpreted differently by individual researchers (Smuda-Kocoń, 2019, p. 74).

In this article, the author decided to use a multidimensional method of statistical analysis — the construction of a classification tree (CART method) using the Statistica 13 software. It is based on the analysis of proprietary diagnostic indicators determining the competitiveness of banks. The indicators used were

developed on the basis of the analysis of reports, rankings and specialized industry studies.

For the purposes of the research, two research hypotheses were put forward:

- H1: Building the competitiveness of modern banks requires taking into account economic capital and subsystems of intellectual capital.
- H2: One-dimensional analysis methods are not sufficient to assess a bank's competitiveness.

The article presents research for the period 2009–2020. The adopted research period is justified by the arguments indicated below. In 2009, the MIFID Directive (Markets in Financial Instruments Directive) was fully implemented into the Polish financial law — this year the Act of September 4, 2008 Amending the Act on Trading in Financial Instruments entered into force. This justifies undertaking research for the Polish banking market, starting from 2009. MIFID regulates issues relevant to the research undertaken. The basic assumption of MIFID was to unify the rules for the provision of investment services in the European Union (i.e. in the 27 EU countries, as well as in Iceland, Norway and Liechtenstein) and to improve the quality of their provision. The Directive allowed for greater competition in the financial services market and greater transparency of the financial market. Particular attention was paid to the regulations concerning the disclosure obligations of investment firms towards clients. The new regulations are intended to prevent misselling, i.e. offering products in a misleading way or offering products that are not tailored to the customer's capabilities or needs. The MIFID Directive meant that banks had to take intensified actions to update their employees' market, product and regulatory knowledge and improve their sales skills and unify the customer service model in this respect. MIFID activities were intensified in 2018 (research period also included in the work), when the MIFID II Directive was implemented into the Polish legal system (Act of 1 March 2018 on Trading in Financial Instruments). MIFID II further tightened the requirements for offering investment products to clients and introduced new requirements for remuneration of sellers/advisers.

The author also points out that in 2009, the Golden Banker plebiscite was introduced on the Polish banking market, in which products offered by banks, distribution channels and service quality are assessed. It is an initiative of the banking and financial sector organized by companies from the Allegro Group — Bankier.pl and PayU S.A. The ranking took into account the bank's high rating in the eyes of customers as a key parameter, emphasizing, among others, the importance of the non-financial elements of these institutions.

The adopted analysis period of 2009–2020 is also related to the pace of introducing innovative solutions in the Polish banking sector and relevant regulatory changes. Since 2009, almost all electronic banking systems in Poland have been modified and expanded. They have become fully functional transactional systems, enabling remote performance of standard financial operations. This is a new dimension at the strategic level — the possibility of interactive management of personal and company finances, including broad access to the offer

of banking and insurance products, brokerage and advisory services. In 2009, there was also an increase in interest in alternative financial innovations in the banking sector — the application of biometrics in banking was presented for the first time. It was the beginning of building a network of biometric ATMs, as well as the banks' aspirations to stand out with further innovative solutions, which later resulted in, among others, development of cooperation with Fin-Tech companies.

The study in the article was based on a group of 10 listed banks included in the portfolio of the WIG-banks sub-index on the Warsaw Stock Exchange. These banks maintain a uniform financial data reporting system, which is the basis for the reliability of analyzes and calculations. An important element is also the full availability of data from the period adopted for the research (2009–2020). The following banks will be the objects of research in the article: Alior Bank, BNP Paribas, mBank; Citi Handlowy (Citi Bank), ING Bank Śląski, Millenium Bank, Pekao Bank, PKO Bank Polski (PKO BP), Santander Bank, BOŚ Bank.

The author, selecting a set of banks to be tested from the portfolio of the WIG-banki sub-index, excluded four entities: UniCredit Italiano, Banco Santander, Getin Holding and Idea Bank. UniCredit Italiano and Banco Santander were obliged to issue their shares on the Warsaw Stock Exchange (this was related to mergers and acquisitions) and in fact these banks do not operate directly in the banking sector in Poland. The Getin Holding capital group includes companies in the area of banking, leasing services and financial intermediation. The financial and non-financial data of the capital group are not comparable with the individual reports of the banks that were included in the study in this article. Idea Bank was also excluded from the study, whose deteriorating financial and economic situation since 2018 led to the forced restructuring process (December 30, 2020), and finally on January 3, 2021 it was taken over by Bank Pekao.

From the point of view of the purpose of the study, the fact that the selected 10 banks gather more than half of commercial banking customers in Poland is of key importance — this makes it possible to attempt to generalize the results of the study. The group of surveyed banks consists of entities that provide the opportunity to obtain comparability of basic performance indicators, numerical characteristics, allowing to verify the degree of advancement of development, taking into account intangible assets, including: digitization, innovation, customer service quality. In this way, a set of determinants of banks' competitiveness was established based on the combined potential of tangible and intangible assets, used in further research (using multidimensional statistical analysis).

The method of multivariate statistical analysis used in the article are classification trees, which use the rule of recursive division. This method consists in a gradual division of the multidimensional space of features (indicators) into disjoint subsets until they become homogeneous due to the distinguished feature y (indicator). Then, in each of the obtained segments, a local model for the y fea-

ture is built. A decision tree is a graphical representation of the recursive division method (Piccarreta, 2008, p. 63). As an exploratory method, it is non-parametric, i.e. it does not assume knowledge of the distribution of features (indicators) or the analytical form of the relationship between them. The selection of features (indicators) in the analysis is automatic based on the adopted criterion, and the obtained model is easy to interpret and shows resistance to unusual observations. in this model, both quantitative and qualitative features (indicators) can be used, without the need to transform them (Park & Kim, 2022, p. 94).

The first paper using the idea of classification trees was the article by Frydman et al. (1985), on Investigating the Creditworthiness and Bankruptcies of Companies. Hołda (2006) was the first paper in the Polish literature on the subject in which CART classification trees were used to analyze the bankruptcy of companies. Interesting results of the comparative analysis of the effectiveness of various methods of multidimensional statistical analysis in forecasting the bankruptcy of industrial processing enterprises are presented in the work edited by Pociecha (2014). The universality of classification trees means that the possibilities of their applications are limited only by the practical needs of researchers regarding the conduct of a given type of analysis — classification(Soewarno & Tjahjadi, 2020, p. 63).The continuous development of classification trees since the 1980s only confirms their usefulness and popularity, and the selected literature items quoted in this article are only a few examples of the application of these methods in practice (creditworthiness, marketing research, bankruptcy of companies, segmentation of the automotive market). The classification tree method will be used to explain the affiliation of individual banks in the analyzed period (in terms of competitiveness) to one of three separate groups (Umanto & Atmoko, 2018, p. 14).

The subject of the analysis is a set of objects (called the learning set *U*), in which each of them is characterized by *m*+1 features (or indicators): [*x*,*y*], where *x*=[*x*_1, *x*_2,..., *x*_*m*]. multidimensional, it can be written in the form of a matrix (Pedro et al., 2018, p. 318):

$$[\boldsymbol{x}_n, y_n]_{n\times m+1} = \begin{bmatrix} x_{11} & \cdots\backslash & x_{1m}, & y_1 \\ x_{21} & \cdots\backslash & x_{2m}, & y_2 \\ \cdots\backslash & \cdots\backslash & \cdots\backslash & \cdots\backslash \\ x_{n1} & \cdots\backslash & x_{nm}, & y_n \end{bmatrix}_{n\times m+1} . \tag{1}$$

Features (indicators) describing the examined objects can be of different nature, the most simplified division is: quantitative and qualitative. According to the generally accepted convention, the indicators *x*_1, *x*_2,..., *x*_*m* are called predictors, and the feature *y* is called the explained (dependent) feature. With the observations of all indicators, the relationship between *y* and *x*_1, *x*_2,..., *x*_*m* should be found so that, based on the variability of the predictor values, it

is possible to determine the values of the dependent feature (Malina & Zeliaś, 1997, p. 38).

One of the most important non-parametric methods of building classification and regression models is the method consisting in assembling local models built in individual subspaces of the m-dimensional feature space X^m. The course of the recursive division procedure is best represented by a tree, i.e. a connected graph without cycles — hence the name of the methods — classification or regression tree. Within the discussed method, a (non-global) model is created by assembling local models of the simplest form, built in each of the K disjoint segments into which the multidimensional feature space is divided (Nan & Yang, 2014, p. 640):

$$y = \sum_{k=1}^{K} \alpha_k I(\boldsymbol{x}_i \in R_k), \tag{2}$$

where: $R_k (k=1,\ldots,K)$ are disjoint areas (segments) in the multidimensional feature space $I(\boldsymbol{x}_i \in R_k)$ is a pointer function. It should be noted that in the above notation of the model, $\boldsymbol{x}_i$ denotes a multivariate observation, and I is an indicator function of the form. It should be noted that in the above notation of the model it means a multidimensional observation, and is an indicator function of the form (Berger et al., 2019, p. 970):

$$I(q) = \begin{cases} 1 & when\ q\ is\ true\ (i.e.\ when\ x_i \in R_k) \\ 0 & otherwise\ (i.e.\ when\ x_i \notin R_k) \end{cases}. \tag{3}$$

If the feature y in the model (3) is a nominal feature, the model is called the classification (discrimination) model and is represented by the classification tree, and the parameters are α_k determined in accordance with the principle of majorization (Xu et al., 2019, p. 45):

$$\alpha_k = arg\max_l [p(l|k)], \tag{4}$$

where: $p(l|k)$ means the probability that a certain object from the segment R_k belongs to the class l — formula (4) says that in the segment R_k the feature y takes the value l, which occurs most frequently.

The division of the multidimensional feature space $\boldsymbol{X}^m$ in the classification problem is done in order to obtain disjoint fragments (segments) of this space R_k — multidimensional cubes in which there are objects belonging to the same class represented by the dependent feature y, taking the values $l=1,\ldots,L$.

The entire analysis is carried out on the training set U, which contains correctly classified objects, and thus on its basis it is possible to find the characteristics of individual classes (model). In the next step, the discovered rules are used to classify new objects (new sets) for which class membership is unknown. Classification trees, as an exploratory method, require a large number of cases (observations) to be analyzed in order to be able to "learn the rules of discrim-

ination" on the basis of the training set, and use the resulting model to classify new objects — the recognized set (Loh, 2009, p. 1715).

The main advantage of the adopted method is that there is no need to know the distribution of explanatory features (indicators) or the analytical form of the relationship between these features and the dependent feature. The model can use both quantitative and qualitative features and it is not sensitive to missing data, which enabled the inclusion in the study of data that had not been reported throughout the study period (Ferreira et al., 2021, p. 54).

4. Results

The study of the impact of intellectual capital on the competitiveness of banks in Poland was conducted on the basis of financial and non-financial data of 10 commercial banks for the years 2009–2020. The database consisted of 26 acceptable indicators, which are presented in Table 1.

The basis for the analysis of banks' competitiveness based on classification trees were the results (places) of the synthetic measure of banks' competitiveness built by the author — ranking 5 (Table 2) — recognized as the optimal solution (author's weights, zeroed unitarization). The three best banks in a given year (places 1–3 in the ranking) formed group A; further banks ranked 4–7 in the tree-based analysis constituted group B; while the last three banks in the ranking (places 8–10) formed group C (Table 3). Thus, a qualitative dependent variable "Group of banks (method 5)" was created, which is the basis for the classification. The aim of the analysis was to find rules which, on the basis of diagnostic indicators used in the construction of the synthetic measure (competitiveness), would allow to classify banks into separate groups (A, B, C). Nevertheless, an additional effect of the analysis is the grouping of banks into homogeneous/or almost homogeneous groups — the results in the terminal nodes of the tree (leaves of the tree). The analysis using the Statistica 13 software was performed on the entire dataset (2009–2020), i.e. 120 observations.

As the optimal result, the Statistica program indicated tree no. 3, containing 7 terminal nodes (Table 4). Finally, the author chose tree No. 2 with 9 terminal nodes — having the same (smallest) cross-validation error SK=0.2833, but giving a lower overall classification error of 0.125 (cost of resubstitution — 12.5%). As a result of the analysis, a classification tree was obtained with a relatively low classification error, having 9 terminal nodes — thus giving 9 classification rules. The classification rules are therefore as follows (the description has been rounded to two decimal places to improve readability):

1. Rule 1 (*X*1, *X*5): If the "return on assets (ROA)" is less than or equal to 0.47% and the share of "bank loans/in banking sector loans (L/SL)" is less than or equal to 5.68%, then these are banks from group C (node 4) — classified ranked 8th–10th.
2. Rule 2 (*X*1, *X*5): If the "return on assets (ROA)" is less than or equal to 0.47% and the share of "bank loans/in banking sector loans (L/SL)" is greater than

5.68%, then are banks from group B (node 5) — classified in the rankings on the 4th–7th place.

3. Rule 3 (*X*1, *X*15, *X*14, *X*15*a*): If the "return on assets (ROA)" is greater than 0.47% and the share of "bank branches/banking sector branches (B/SB)" is less than or equal to 14.08% and "value of training/total value of employee benefits (T/TB)" is less than or equal to 3.49% and "number of branches per 10,000 customers (B/C)" is less than or equal to 0.42, these are banks from group C (node 12) — classified in the rankings on the 8th–10th place.
4. Rule 4 (*X*1, *X*15, *X*14, *X*15*a*): If the "return on assets (ROA)" is greater than 0.466% and less than or equal to 1.34% and the share of "bank branches/in banking sector branches (B/SB)" is less than or equal to 14.08% and "training value/total value of employee benefits (T/TB)" is less than or equal to 3.49% and "number of branches per 10,000 customers (B/C)" is greater than 0.42, these are banks from group B (node 14) — classified in the rankings on the 4th–7th place.
5. Rule 5 (*X*1, *X*15, *X*14, *X*15*a*, *X*7): If "Return on Assets (ROA)" is greater than 1.34% and the share of "bank branches/in banking sector branches (B/SB)" is less than or equal to 14.08% and "value of training/total value of employee benefits (T/TB)" is less than or equal to 3.49% and "number of branches per 10,000 customers (B/C)" is greater than 0.42 and the share "customers actively using online banking/total customers (in %) (EB/C)" is less than or equal to 49.73%, these are banks from group B (node 11) — classified in the rankings on the 4th–7th place.
6. Rule 6 (*X*1, *X*15, *X*14, *X*15*a*, *X*7): If the "return on assets (ROA)" is greater than 1.34% and the share of "bank branches/in banking sector branches (B/SB)" is less than or equal to 14.08% and "value of training/total value of employee benefits (T/B)" is less than or equal to 3.49% and "number of branches per 10,000 customers (B/C)" is greater than 0.42 and the share "customers actively using online banking/total customers (in %) (EB/C)" is greater than 49.73%, these are banks from group A (node 25) — ranked 1–3 in the rankings.
7. Rule 7 (*X*1, *X*15, *X*14, *X*15*a*): If the "return on assets (ROA)" is greater than 0.47% and the share of "bank branches/banking sector branches (B/SB)" is less than or equal to 14.08% and "value of training/total value of employee benefits (T/TB)" is greater than 3.49% and "number of branches per 10,000 customers (B/C)" is less than or equal to 0.66 these are banks from group B (no. 26) — classified in the rankings on the 4th–7th place.
8. Rule 8 (*X*1, *X*15, *X*14, *X*15*a*): If the "return on assets (ROA)" is greater than 0.47% and the share of "bank branches/banking sector branches (B/SB)" is less than or equal to 14.08% and "value of training/total value of employee benefits (T/TB)" is greater than 3.49% and "number of branches per 10,000 customers (B/C)" is greater than 0.66, these are banks with group a (no. 27) — classified in the rankings on the 1st–3rd place.

9. Rule 9 (*X*1, *X*15): If the "return on assets (ROA)" is greater than 0.47%, and the share of "bank branches/banking sector branches (B/SB)" is greater than 14.08%, these are banks from group A (node 9) — ranked 1–3 in the rankings.

It is also worth paying attention to the order in which the indicators appear in the tree chart and the number of nodes. Economic capital indices (*X*1, *X*5) were used as the first to discriminate banks — left branch, which helped to classify 36 bank ratings (nodes 4–5, containing 30% of observations). Subsequently, organizational capital indicators (*X*15, *X*15*a*) — a branch of law, which helped classify 13 bank ratings (node 9, containing 11% of observations). Then, in the middle part of the tree, in conjunction with the indicator from the innovative capital layer (*X*14) and further from the ORG, EC and INN layers, 71 bank ratings could be classified (nodes 12, 14, 24–27, containing 59% of observations). Based on this type of tree chart analysis, it can be concluded that in assessing the competitiveness of banks (as well as in explaining their belonging to the appropriate group A, B, C) the key factors (in order) were indicators from the economic capital (EC), organizational (ORG)) and innovative (INN), and indicators from the layer of institutional capital (INS) were not taken into account at all.

Another way to interpret the results of the tree is to give the probabilities of classifying objects (banks) in a given terminal node — leaf:

- node 4, banks in this leaf are classified to group C with probability 0.9655;
- node 5, banks in this leaf are classified to group B with probability 0.7143;
- node 12, banks in this leaf are classified to group C with probability 1.0000;
- node 14, banks in this leaf are classified to group B with probability 0.8235;
- node 24, banks in this leaf are classified to group B with probability 0.7273;
- node 25, banks in this leaf are classified to group a with probability 1.0000;
- node 26, banks in this leaf are classified to group B with probability 1.0000;
- node 27, banks in this leaf are classified to group a with probability 0.8235;
- node 9, banks in this leaf are classified into group a with probability 1.0000.

It is worth noting that the four most important — the most numerous — terminal nodes of the tree are:

- node 4 (ID=4), containing a total of 29 facilities — where banks from group C predominate and there is 1 bank from group B;
- node 14 (ID=14), containing a total of 34 facilities — 28 banks from group B and 4 and 2 banks from group C and A, respectively;
- node 27 (ID=27), containing a total of 17 facilities — 14 banks from group A and 3 banks from group B;
- node 9 (ID=9), containing a total of 13 objects (banks) from group A.

Therefore, it can be summarized that the most important rules in the tree (according to the above node order) are rule 1, rule 4, rule 8, rule 9. In each of these cases, it should be emphasized that belonging to specific nodes was primarily determined by the indicators determining economic capital, while the indicators defining the layers of intellectual capital constituted the added

value. The analysis carried out using classification trees revealed the key role of economic capital as the basis for the bank's development, because when determining the banks' affiliation to each group A, B, C (according to their places in the competitiveness ranking), the indicators from the economic capital (EC) layer were of key importance, followed by the organizational (ORG), innovative (INN).

The multidimensionality of the bank's competitiveness requires the use of methods that emphasize not only the basis of its development (economic capital) but also the possibility of intellectual capital, which leads to a positive verification of the article H2, saying that one-dimensional analysis methods are not sufficient to assess the bank's competitiveness. The results of research using classification trees and the earlier analysis of the structure of the subject and the empirical research of the authors formed the basis for the H1 verification, which said that building the competitiveness of modern banks requires taking into account economic capital and subsystems of intellectual capital.

5. Conclusion

The concept of competitiveness is addressed in most economic schools and is constantly evolving. In recent decades, in the works of various authors, the impact of the potential of intangible resources on achieving a stable, long-term competitive position in a dynamically changing environment is increasingly emphasized. The analysis of the literature on the subject and the review of the determinants of the competitiveness of banks show that bank managers should focus especially on the development of innovative products and services, customer satisfaction, flexible organizational structure, systematic modernization, including making the management system more flexible, and above all, find a way to accelerate the ability to adapt to change. The dynamics of the environment is growing at an ever-increasing pace, and entities incapable of capturing the latest trends lose their market positions.

Banks striving to consolidate the acquired competitive advantages should definitely and unquestionably take care of the condition of their economic capital (volume of assets, loans, deposits, efficiency ratios). It is the basis for building long-term competitiveness, the foundation without which it is impossible to create added value to the constantly growing market standards. Dominance in this respect against the background of competitors is even desirable, because it gives an initial advantage (basic competitiveness). However, in the long term, this is not a sufficient potential to maintain a competitive advantage. It is necessary to draw competitive capabilities (operational competitiveness) from various sources, inherent in intangible assets, i.e. relations with the environment, image, models of CSR implementation, ways of exploring (not exploiting) key employee competencies, in order to ensure high-quality service for its market segments. In this way, on the basis of intellectual capital (IC), including innovations (innovative capital, INN), organization of structures (organizational

capital, ORG) and the relationship model (institutional capital, INS), the bank creates competency competitiveness (based on the key competences of a given entity).

Due to the multidimensionality of the bank's competitiveness issues, relating not only to base performance indicators, but also to operational, competency and system effectiveness, it seems appropriate to include tangible and intangible aspects as related sources of synergistic competitive advantage. The study of the importance of intellectual capital in building the competitiveness of banks, due to the complexity of the concept of "intellectual capital" and the concept of "competitiveness", required the use of multidimensional statistical methods. The method used in the article were classification trees, using the rule of recursive division. This method did not require knowledge of the distribution of features (indicators) or the analytical form of the relationship between them. The selection of features (indicators) in the analysis was automatic based on the adopted criterion, and the obtained model was easy to interpret and showed resistance to atypical observations.

Based on the conducted research, the role of intellectual capital in assessing the competitive position of a bank became visible. The author pointed out that among the most important rules in the tree (according to the established order of nodes) that determined the affiliation of banks to group A (i.e. places 1–3 in the competitiveness ranking) were rule 1, rule 4, rule 8, rule 9. These rules included economic capital ratios and the value of training/total value of employee benefits (T/TB), defining innovative capital, and the ratios: number of branches/number of banking sector branches (B/SB), number of branches per 10,000 customers (B/C), which indicate organizational capital. The fact that rule 1 defining economic capital is indicated by the classification tree as the most crucial one does not undermine the importance of studying the impact of intellectual capital on the bank's competitiveness, because as assumed in the article, economic capital plays the role of an indispensable foundation in building the competitiveness of banks.

The author noted that the emphasis on the key role of the bank's intellectual capital as a determinant of competitiveness in empirical research by various authors meant that the IC concept became part of the theory of managing banks as enterprises. Thus, there was a clear reference to the microeconomic theoretical background of the analyzes of the competitiveness of banks, especially the resource theory. Researchers and practitioners now quite commonly recognize that IC is a driving force for maintaining a strong competitive position in a dynamic environment. This applies to fundamental results (determined by measures of efficiency and profitability) as well as creating organizational value, creating added value, and sustainable development. The author of the article would like to point out that the subject of intellectual capital is constantly evolving due to the increasing role of relationality, innovation and digitization in the banking sector. Therefore, the banks' reports may potentially include further indicators characterizing individual subsystems of intellectual capital.

The research carried out in can be a starting point for further research and attempts to standardize reporting and methods of assessing the impact of intellectual capital on the competitiveness of banks.

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Appendix

Table 1.
Accepted indicators included in the study

Capital	Symbol	Name	The nature of the indicator
EC	*X*1	ROA	S
EC	*X*2	ROE	S
EC	*X*3	NIM	S
EC	*X*4	CIR	D
EC	*X*5	loans/loans sector (L/SL)	S
EC	*X*6	sector deposits/deposits (D/SD)	S
INN	*X*7	number of clients actively using internet banking/number of clients (EB/C)	S
INN	*X*8	number of clients actively using the mobile application/number of clients (MB/C)	S
ORG	*X*9	employee benefits/number of employees (C/E)	S
EC	*X*10	profit/number of employees (P/E)	S
EC	*X*11	sales revenues/assets (S/A)	S
INS	*X*12	Ranking Bankier — place in the ranking	D
INS	*X*12_*a*	Banker ranking — results in the overall ranking	S
INN	*X*14	value of training/employee benefits (T/C)	S
ORG	*X*15	number of branches/number of branches sector (B/SB)	S
ORG	*X*15_*a*	number of branches/number of clients (B/C)	S
EC	*X*16	capital adequacy ratio	S
EC	*X*17	ROS	S
ORG	*X*18	number of clients/number of employees (C/E)	D
INN	*X*19	training value/number of employees (T/E)	S
EC	*X*20	loans/deposits (L/D)	N
EC	*X*21	assets/sector assets (A/SA)	S
INS	*X*22	number of awards granted (INC)	S
INS	*X*22_*a*	number of awards granted/number of awards commercial banks	S
INS	*X*23	good CSR (GP) practices	S
INS	*X*23_*a*	good CSR practices/good practices commercial banks	S

Notes:

S — the stimulant; D — the destimulant, N — the nominate.

Source: Own preparation.

Table 2.
Synthetic measure and ranking of banks using the system of author's weights and zero unitarization

Bank	2009		2010		2011		2012		2013		2014		2015		2016		2017		2018		2019		2020	
	KB	R	KB	R	KB	R	KB	R	KB	R	KB	R	KB	R	KB	R	KB	R	KB	R	KB	R	KB	R
Alior Bank	0.2565	10	0.4003	8	0.4044	7	0.4405	8	0.3706	8	0.4073	8	0.4478	6	0.4132	7	0.4776	7	0.4138	8	0.2645	9	0.3268	9
BNP Paribas	0.4178	6	0.2965	9	0.2578	10	0.2850	9	0.2706	9	0.3449	9	0.4244	9	0.3200	10	0.3424	9	0.4358	7	0.4439	6	0.6183	3
BOŚ	0.3143	9	0.2729	10	0.2920	9	0.2517	10	0.2216	10	0.2435	10	0.2790	10	0.3693	9	0.3229	10	0.2158	10	0.1877	10	0.2025	10
Citi Handlowy	0.5791	3	0.5351	5	0.5408	4	0.5870	3	0.5294	5	0.4671	7	0.4459	7	0.3879	8	0.4134	8	0.4887	6	0.3833	8	0.4319	8
ING Bank	0.5598	4	0.5421	4	0.4866	5	0.5442	5	0.5870	3	0.4980	4	0.6215	3	0.5242	4	0.5406	4	0.6126	2	0.5005	3	0.6729	1
mBank	0.3816	7	0.5274	6	0.4329	6	0.4950	6	0.5011	6	0.4694	6	0.4437	8	0.4625	5	0.5044	6	0.5001	4	0.4624	5	0.4976	7
Millenium Bank	0.3789	8	0.4632	7	0.3579	8	0.4839	7	0.4653	7	0.4915	5	0.5085	5	0.5528	3	0.5556	3	0.5333	3	0.4403	7	0.5416	5
Pekao Bank	0.6629	2	0.5909	2	0.5654	3	0.5482	4	0.5309	4	0.5157	3	0.5543	4	0.4500	6	0.5294	5	0.3983	9	0.4842	4	0.5477	4
PKO BP	0.6947	1	0.7112	1	0.6814	1	0.7025	1	0.6447	1	0.6515	1	0.6824	1	0.6396	1	0.6997	1	0.6134	1	0.6712	1	0.6681	2
Santander Bank	0.4993	5	0.5552	3	0.6269	2	0.6318	2	0.6118	2	0.6266	2	0.6391	2	0.5898	2	0.6208	2	0.4942	5	0.5570	2	0.5048	6

Notes:

KB — value of the synthetic measure of banks' competitiveness; R — position in the ranking.

Source: Own preparation.

Table 3.
Groups of places based on the optimal ranking (ranking 5)

Bank	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	R	R	R	R	R	R	R	R	R	R	R	R
Alior Bank	C	C	B	C	C	C	B	B	B	C	C	C
BNP Paribas	B	C	C	C	C	C	C	C	C	B	B	A
mBank	B	B	B	B	B	B	C	B	B	B	B	B
Citi Handlowy	A	B	B	A	B	B	B	C	C	B	C	C
ING Bank	B	B	B	B	A	B	A	B	B	A	A	A
Millenium Bank	C	B	C	B	B	B	B	A	A	A	B	B
Pekao Bank	A	A	A	B	B	A	B	B	B	C	B	B
PKO BP	A	A	A	A	A	A	A	A	A	A	A	A
Santander Bank	B	A	A	A	A	A	A	A	A	B	A	B
BOŚ Bank	C	C	C	C	C	C	C	C	C	C	C	C

Source: Own preparation.

Table 4.
Statistica 13 analysis results — tree sequence

No	Final nodes	SK cost	SK error	Redistribution cost	Complexity node
tree 1	12	0.33333	0.043033	0.10000	0.0000000
tree 2	9	0.28333	0.041136	0.12500	0.0083330
tree 3	7	0.28333	0.411136	0.15000	0.0125000
tree 4	5	0.31667	0.042465	0.20000	0.0250000
tree 5	4	0.32500	0.042757	0.23333	0.0333330
tree 6	3	0.35000	0.043541	0.30000	0.0666670
tree 7	2	0.41667	0.045005	0.40833	0.1083330
tree 8	1	0.60000	0.044721	0.60000	0.1916670

Source: Own preparation.