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Diversity Management in Management Studies – Theoretical Discussion

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ABSTRACT

Objective: The aim of this article is to attempt to present theoretical considerations towards the concept of diversity management from the perspective of its location in the discipline of management and quality sciences. As the concept of diversity management lacks a strict demarcation between related disciplines, such as economics, psychology, sociology or even biology and cultural anthropology, it should be noted that the specification of paradigms is not closed, and further paradigms, micro-paradigms or mega-paradigms may emerge over time.

Methodology: the research method adopted in the article is literature analysis and inference.

Findings: The approach presented, which points to the permanent development of alternative paradigms and cognitive perspectives in the discipline of management and quality sciences, is a confirmation that these 'sciences' are not 'impregnated' against change and are de facto changing.

Value Added: Consideration of the issue of human capital diversity in organisations and its management has been carried out for many years in the literature, which is characterised by a diversity of definitions and perceptions. It is therefore worth presenting, a cross-cutting historical perspective on the phenomenon of human resource diversity in organisations in the discipline of management and quality sciences.

Recommendations: Diversity management should be defined in the broadest possible way, understanding it as the systematic efforts of an organisation to involve the diversity of its human resources in its activities and to treat it as a strategic advantage. Such a conclusion prejudices the need for further research in relation to the concept of diversity management.

Key words: diversity management, management studies, theory

JEL codes: B290, C120, M500

Introduction

Phenomena and processes that are a kind of *signum temporis* – globalisation, technological developments, the information society, networking – are relevant for changing at least some of the established regularities or theories about management. R.W. Griffin wrote that one of the main challenges faced by managers, alongside declining production and employment, is managing diversity (Griffin, 2013, pp. 60–61). There are discussions in the literature, business circles and the media about how to approach and apply diversity management in practice. It is often seen as part of human resource management, knowledge management, and less often as part of strategic and organisational value management. It is therefore worth presenting a cross-cutting historical view of looking at the phenomenon of human resource diversity in organisations – using current nomenclature – in the discipline of management and quality sciences. It can be said that common classical management concepts are still taken into account in the process of learning about and understanding this issue.

From the perspective of classical management concepts

A few words, therefore, about the classical management concepts. The concept of scientific management created and popularised by eminent scientists (F.W. Taylor, H. Fayol, K. Adamięcki, M. Weber, H. Emerson), which is now more than 100 years old and sparked a century-long search for the right balance between “things of production” and “people of production” (Taylor, 1922; Taylor, 1947; Adamięcki, 1938; Bendix, 1975; Emerson, 1926; Fayol, 1930) or between “specialists in numbers” and “humanists” (Kiechel, 2013). An important influence on organisational and management science was the book published by F.W. Taylor in 1911, *The Principles of Scientific Management*, which brought an engineering discipline in the form of what was known as ‘running a business’. At that time, employers thought that all employees could be

treated the same and that the common motivator was money. The limitation of this classical view was an approach that neglected the role of the individual in the organisation, which is contrary to the concept of diversity management. In general, however, it can be said that the scientific management current was already addressing one dimension of counter-productivity – low labour productivity, which, according to the aforementioned researchers, was due to several causes. On the one hand – from the negative inclinations and habits of the individual (e.g. laziness), and on the other – from the lack of developed working methods, appropriate working conditions, rules of conduct or – emphasised by contemporary researchers – unfair treatment by superiors (Piotrowski, 2000, p. 642). In general, however, a certain weakness of the classical currents was the insufficient attention paid to the working man and the tasks imposed on him by the organisation. This gap became the basis for the development of another trend in organisational and management theory referred to as the behavioural school, within which the human relations direction became the most important, whose founders included: E. Mayo, D. McGregor, H. Münsterberger, F.J. Roethlisberger, A. Maslow, F. Herzberg) (Maslow, 1943; Münsterberger, 1913; Roethlisberger, 1939). For example, research conducted by E. Mayo (Kozminski, 2010) at the Hawthorne facility, Chicago, between 1924 and 1932, began to cast doubt on the theories of the time. This researcher found that working conditions, social factors and group dynamics were also important factors influencing employee behaviour. He then showed the complexity of the motivation process. In essence, the researchers mentioned above emphasised the role of the social context (group and cultural influences) and individual human needs. Above all, in their reflections, they focused attention on low individual productivity, conflicts, excessive absenteeism at work, excessive staff turnover or the increase in employee dissatisfaction. Among the causes of such phenomena, they saw a failure to take into account the diverse psychosocial needs of organisational participants and management's suppression of informal groups (e.g. the disadvantaged). The key to increasing work performance, therefore, was to seek the acceptance of organisational goals by informal groups and to use the influence of informal groups to enhance the efficiency of the management process and increase productivity. In this context, it should be noted that researchers

of the behaviourist direction in management theory have pointed out that the source of people's motivation to work is the need for belonging, security and recognition that each individual has and wants to fulfil in the workplace. High morale and high levels of employee satisfaction, according to humanists, were to be achieved through the display of benevolent interest by superiors. Mainly, a person's participation in an institution is supposed to be the more reliable and productive, the higher his morale is (i.e. the more positive his attitude towards the organisation as a whole, the social group of which he is a member, the organisational function he performs, etc.) – and the more satisfied he or she is with his or her work situation, and this satisfaction stems from the satisfaction of social needs (Piotrowski, 2010, pp. 665–692). This approach popularised the idea that, on the one hand, employees are a rather valuable resource for an organisation and, on the other hand, managers had to take into account the aspect of human satisfaction at work (Gross-Gołacka, 2018).

The impact of modern thinking

The Polish praxeological school with its representatives – T. Kotarbinski (1958, 1970, pp. 120–122) and J. Zieleniewski (1969), who dealt with the principles of conscious human action is also worth noting. These authors focused attention on efficient action by constructing certain guidelines to serve this purpose. In his *Treatise on Good Work*, T. Kotarbinski wrote, among other things, that the concepts used to pronounce praxeological judgements were, for example: economy, efficiency, accuracy of execution, certainty of the methods used (Kotarbinski, 1955, p. 23). The school of the praxeological trend in Poland has evolved to come closer to a systems approach.

Another notable contribution to modern management thinking (including the concept of diversity management) is the aforementioned systems school, which advocated considering the organisation in its environment (L. von Bertalanffy, K. Boulding, S. Beer, J.W. Forester, N. Wiener et al., L. Kantorowicz, G. Nadler et al.) (von Bertalanffy, 1984). In this approach, an organisation is

identified as a system, i.e. a whole consisting of interrelated elements that are in various types of interaction with the environment. In essence, the recognition of the organisation as a system has 'opened' it up to the influences of the environment, while at the same time making the environment sensitive to its actions. This perspective therefore appears to be relevant to the development of the concept of diversity management in organisations. It shows that the management of diverse resources is just as important as, for example, material resources and both interact. In addition, the dynamism of the organisation and its environment makes the organisation different at each moment of its existence from its previous state, which at the same time requires it to be flexible and adaptive to the changing reality.

Continuing the considerations in the proposed scope: it was considered appropriate to mention the achievements of the representatives of the neoclassical school, which was a response to the existing discrepancies between theory and practice. Among the main achievements of the representatives of the neoclassical school, it is worth noting (Borowska-Pietrzak, 2010, pp. 75–86; Lisiecki 2001, p. 78; Kieżun, 1997, pp. 72–74; Chrisidu-Budnik et al., 2005, p. 98): the concept of motivation through participation (P. Drucker), the conceptual model (F.E. Kasta, J.E. Rosenzweig), the model of two types of enterprise organisation – mechanistic and organic (T. Burn, G.M. Stalker), the influence of the external environment on the structure of the enterprise (P.L. Lawrence, J.W. Lorsch), the influence of technology on the organisational structure of the enterprise (J. Woodward, C. Perrow), the links between staff motivation and organisational form (S. Morse), the situational model of leadership (P. Hersey, K.H. Blanchard). Essentially, the neoclassical school emphasised the complexity of the problems occurring in an organisation and the dependence of these problems on internal and external factors. Furthermore, it advocated choosing solutions that are best for the organisation in view of the conditions that exist. From the neoclassical school, a new-wave current in management emerged in the early 1980s (R.T. Pascale, A.G. Athos, T.J. Peters, F.H. Waterman, R.H. Waterman, W. Ouchi), which was the result of a crisis in theory that gave way to a fascination with the experiences of companies that were achieving better results. The research and analysis (mainly of practice) carried out within this strand made it possible to identify certain solutions in the form of

identified regularities (a package of key characteristics of the most effective and excellent companies) and irregularities (a set of ‘cardinal sins’) committed by managers (Borowska-Pietrzak, 2010, p. 83). Attention has been paid to the factors that generate dysfunctions in effective organisational management.

Postmodernists point to the organizational culture, describing it as unstable, incoherent – the approach differentiating the organizational culture based on dichotomy was opposed. Uncertainty is also perceived in a different way, where, according to postmodernists, uncertainty has been recognized as a certain feeling, a state that should be considered as a stimulus to take action. The issue of power, or rather the prevention of its accumulation at the top of the organisational pyramid, was analysed, which addressed the issues of limited democracy and limited participation of groups hitherto marginalised in the organisation, such as “women, racial and ethnic minorities, mature people and young people”, which seems relevant from the perspective of the development of the concept of diversity management.

Also Ł. Sułkowski (2012, pp. 35–55) notes that modern organisations need to focus on other principles of work organisation. He points out that the key to competing is the development of teamwork, and that employees should bear responsibility for the course of the entire organisation’s processes, and not only specialised and hard-to-identify fragments. Particularly noteworthy is the aspect raised that concern for quality and commitment to organisational improvement should be a matter for all employees, not just managers. There is also a need for the development of social contacts, interactions and the enrichment of organisational culture, leading to the strengthening of cooperation between employees. In Poland, the postmodern trend has its supporters (M. Kostera, L. Krzyżanowski) and opponents (A.K. Koźmiński).

About diversity management

On the basis of the preceding considerations, it is noted that the issue of diversity management has been present in the literature for many years, it tended

to be seen essentially in terms of optimising individuals and organisations, although it has evolved with the development of management concepts (Nweiser & Dajnoki, 2022). Initially, the assumption was that the employee would perform more effectively and, therefore, individual non-economic motivations were sought to be understood, in particular motivations related to the need to coexist with the group, to the search for recognition and prestige among workers. However, there was no extensive discussion of the nature of behaviour unfavourable to such behaviour (e.g. discrimination, unequal treatment, mobbing) of employees (including managers) and their subjective, organisational and social conditions or the various manifestations of such behaviour. It seems, therefore, that such a multifaceted coverage of this topic is quite rare. This is also noted by Y. Vardi and E. Weitz, who believe that the neglect of this research area in the management sciences is largely due to the nature of these sciences: within which functionalism and positive orientation are the dominant paradigms (Vardi & Weitz, 2004, p. 9).

Functionalism, or the neo-positivist-functionalist-systems (NFS) paradigm prevalent in management science, is characteristic of both the scientific management and human relations currents. This approach views the organisation as a system made up of interrelated parts, each of which has a function in the system (e.g. recruitment, motivation, professional development or remuneration), which at the same time strives in dynamic equilibrium to maintain order and function optimally. In principle, such an approach, may obscure, or even dismiss, the behavioural and interactional level of the organisation. It seems that dismissing any unlawful or unethical behaviour from the analysis will result in treating it as a temporary deviation from the norm rather than a permanent dysfunction of the system/process. With such an approach, interpretations of the processes of: establishing and exercising power and ownership, communication of individuals and teams, formation of cultural elements or making sense of organisational reality (Sułkowski, 2012, p. 116) – important for the concept of diversity management in organisations – may be lost. Furthermore, the NFS paradigm may be a limitation for a complete account of diversity management in organisations due to its ‘positive nature’. What this means is that in corporate science, it is a vision of human beings doomed to

hyper-rationality. Organisations, on the other hand, focus on increasing efficiency, economic profitability, rather than diagnosing dysfunctions in the management process. The aim is to increase the level of motivation among employees and greater commitment, professional development or increased employee satisfaction for increased efficiency and productivity. It is, however, critical to note that this functionalist-systems orientation in management overlooks many problems related to workplace inequality, discrimination, mobbing or harassment – important aspects for the concept of diversity management. It is also worth noting that the level of analysis relates more to the organisational or socio-cultural system and much less to the level of employee behaviour within the organisation (Gross-Gołacka, 2018).

Paradigms and multi-paradigms

Taking the above into account, it is worth adopting the approach proposed by Ł. Sułkowski, who points out that in the management sciences, it is possible to see an increase in the importance of alternative paradigms that move away from the classical understanding of organisation and management associated with economic and technical sciences (Sułkowski, 2012, p. 343).

Table 1. Dominant versus alternative paradigms

Criteria	Dominant paradigm	Alternative paradigm
Relationships between the components of reality	Cause and effect, repeatable	Interdependencies, recurrent and individual
Objectives of the study	Generalisation, versification, analysis, anticipation and programming of change	Understanding, description, synthesis, stimulating change
Relationship of the researcher to the reality under investigation	Objective, external point of view (outsider)	Participant in the phenomena and processes under investigation (insider)
Relationship of the researcher to values	Striving for objective, value-free knowledge	Consciousness entangled in values (axiological attitude)

Criteria	Dominant paradigm	Alternative paradigm
Preferred methodology	Explanatory, providing predictions based on abstract systems of concepts	Descriptive/explanatory or understanding (hermeneutic)
Preferred methodology	Standardised, quantitative, structured methods	Non-standardised, qualitative, unstructured methods

Source: (Sułkowski, 2012, p. 101).

It is worth mentioning that the concepts of corporate social responsibility, sustainable development of the enterprise, human capital, self-realisation and employee subjectivity originated in the field of management sciences and also include the aspect of humanisation of management. Ł. Sułkowski (2012, p. 170) suggests that ideas drawn from alternative paradigms, such as empowerment or diversity management, are only selected examples of approaches that reject instrumental rationalism. Problems of power, group communication and organising group action are of broad interest to many social sciences, humanities and even natural sciences (e.g. evolutionary biology, cognitive science), and admit of multiple points of view. Thus, a strict demarcation between the concerns of different sciences is unnecessary; indeed, greater interdisciplinarity with other sciences and a dose of epistemological pluralism is necessary (Sułkowski, 2012, pp. 170–173).

Diversity management – multiple perspectives

As diversity management can be analysed from many perspectives – both as an organisational or socio-cultural system and from the level of employee behaviour in the organisation – it seems worthwhile to identify the theories of the dominant paradigm (functionalism, neo-positivism, systems theory) *versus* alternative paradigms (interpretivism, critical current). Adopting such a way of thinking would provide an opportunity to generate knowledge to 1) identify the main barriers arising from diverse human resources in an organisation in

the form of: discrimination, culture shock, xeno- or homophobia, attribution errors and the mechanisms that govern them, 2) propose ways and tools to eliminate them, and 3) provide principles and ideas to benefit business from diversity. This approach points to the rapid development of alternative paradigms and cognitive perspectives, which means that management science is not ‘impregnated’ to change.

Conclusion

The concept of diversity management as a discipline area of management and quality sciences is characterised by a significant influence of other scientific disciplines and a lack of strict demarcation between related disciplines such as economics, psychology, sociology or even biology and cultural anthropology. It should be made clear that the presented specification of paradigms in management is perhaps not complete enough, although the intention was not to include all significant approaches. It is probably not closed, and further paradigms, micro-paradigms or megaparadigms may emerge over time. It is clear that the current paradigms of the discipline of management and quality sciences revolve around the human being in the organisation. The behavioural approach has established the importance of the human factor in organisations, highlighted the importance of group dynamics and the complexity of human motivation. It also focuses on the systems approach, which has identified the organisation as a collection of elements that are interconnected by relationships, which is directed towards the achievement in the optimum possible way of specific goals or activities. Diversity is defined by a mixture of many factors of both differences and similarities, as the largest array of different categories of characteristics. This approach shows that diversity cannot be easily defined in terms of a closed catalogue of characteristics. There is a great deal of variability and diversity. The result of this diversity in an organisation is a valuable differentiated team that contributes, among other things, to diverse experiences, different points of view that foster cooperation, creative

problem-solving, innovation and creativity. And diversity management should be defined in the broadest possible way, understanding it as the systematic efforts of an organisation to involve the diversity of its human resources in its activities and to treat it as a strategic advantage. Such a conclusion prejudices the need for further research into the concept of diversity management.

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Behavioral Accounting: A Bibliometric Analysis of Literature Outputs in 2013–2022

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ABSTRACT

Objective: Comprehensive overview of the most current topics, trends and scientific production in the field of behavioral accounting.

Method: A bibliometric approach was applied to analyze data extracted from the Scopus database covering the period 2013–2022. R software and VOS viewer were used to determine the relevant parameters of the studied papers and create scientific maps of collocations.

Findings: An analysis of selected 270 papers has shown that behavioral accounting is a rather scattered area both in terms of publication outputs as well as the conceptual apparatus, including the keywords used by scientists dealing with such issues. This makes it much more challenging to synthesize its output to date and probably slows down the process of crystallizing its scientific identity.

Value Added: It is a diagnosis of the current state of the art within behavioral accounting that can be treated as a continuation of the literature reviews made so far by means of more “manual” methods; however, the first performed with the use of bibliometric tools and devoted exclusively to that topic.

Recommendations: It would benefit the field’s development if researchers parameterized their outputs to facilitate the synthesis of the current state of knowledge within behavioral accounting.

Key words: Behavioral Accounting, Bibliometric Analysis, Science Mapping

JEL codes: D81, D91, G41, M49

Introduction

Behavioral accounting can still be named a quite young field of knowledge, although the research that refers to it has been carried out for about 70 years if we consider Argyris' works done in the 1950s as its beginning (Argyris, 1952). Its lingering immaturity, despite increasing popularity among the research community in the last years, is due to its scientific foundations not being fully formed. Neither the definitions of behavioral accounting nor its research areas have been sufficiently clarified (Korzeniowska, 2018). This may stem from the strong ties to behavioral economics or behavioral finance and the interpenetration of these disciplines. In particular, quite often, it is difficult to clearly determine whether a given study is situated within behavioral accounting or rather behavioral finance as both draw, i.a., on psychology, sociology or decision theory, and much of the area of their interest concerns judgement and decision-making biases made when analyzing financial data. In the absence of precise definitions of these fields, this is all the more difficult.

In 1989 Lord described 'behavioural accounting' in very general terms naming it "the multidisciplinary field that draws from the theoretical constructs of the behavioral sciences" (Lord, 1989). However, he did not elaborate on what is meant by 'behavioural sciences'. Bruns (1973) several years earlier stated that "the question of how broadly behavioural accounting should be defined will have to be decided ad hoc by each researcher". Hence, any researcher who situates his research in the realm of behavioural accounting will have to define by himself, for the purposes of own research, what he believes behavioural accounting is about.

Behavioural accounting research (BAR) can be primitively, as defined by Hofstedt (1976, p. 3), framed as those articles or books published in the accounting literature that use theories and data from the social sciences for implicit or explicit application to management practice and problems. In his view, such framing is sufficient to decide whether to qualify or not a publication for BAR and to make further analyses or syntheses based on such assumption. There are many other general notions e.g. stating that "behavioral accounting is an offspring from the union of accounting and behavioral science (Report of The Committee, p. 127), or that it is the application of the methods

of the behavioral sciences and their views to accounting, and that its primary purpose is to explain and predict human behaviour in all possible aspects and contexts related to accounting (Belkaoui, 1989). Siegel and Ramanauskas-Marconi (1989) emphasize additionally that behavioral accounting is a dimension of accounting related to human behaviour and its relationship to the planning, construction and use of an effective accounting system.

Ashton (2013, p. 115) made a kind of summary of the research interests of behavioural accounting researchers. According to him, the scope of behavioural accounting research can include the behaviour of accountants, the impact of behaviour on the design and use of the accounting system, the impact of the accounting function on behaviour, and the impact of accounting information on those who receive that information. Still, the scope of this concept has not been fully exhausted.

Regarding literature reviews of behavioral accounting research, one of the earliest attempts was that by Hofstedt (1976). In his paper of 1976, he reviewed the literature published between 1964 and 1975 in three journals: “Accounting Review”, “Journal of Accounting Research” and “Empirical Research in Accounting: Selected Studies”. The year 1989 was quite rich in works of a review nature (five, to be precise). It should be mentioned that this year a journal strictly devoted to research in this area, i.e. Behavioral Research in Accounting, was established. Burghstaler and Sundem (1989) reviewed the literature on behavioral aspects of accounting published between 1968 and 1987 in three journals i.e., “The Accounting Review”, “Journal of Accounting Research” and “Accounting, Organizations and Society”. Lord (1989) in his paper summarized the development of behavioral thought in accounting (as he called it) between 1952 and 1981. Another input was made by Siegel and Ramanauskas-Marconi (1989 after Se Tin et al., 2017), Caplan (1989), and Birnberg and Shields (1989). However, the latter tend to be rather opinions laden with some degree of subjectivity which makes them quite far from a “classic” literature reviews.

In following years significant contribution was made by Bamber (1993), who collected articles published in 1987–1991 in nine leading accounting journals (incl. “Accounting Review”, “Journal of Accounting Research”, “Behavioral Research in Accounting”, “Accounting, Organizations and Society”).

It should be emphasized, however, that Bamber's main goal was not only to summarize the previous BAR output but, first and foremost, to create a base for exploring opportunities for further research within its specific topics and subareas. The subsequent two literature reviews adopted diverse scope; they summarized BAR's work to date and grouped it into research areas following the ex-post perspective (what has been researched) rather than an ex-ante perspective (what can be further researched). They were based on an analysis of articles published in *Behavioral Research in Accounting* in 1989–1998 (Meyer & Rigsby, 2001) and 1999–2008 (Kutluk & Ersoy, 2011).

Birnberg, in 2011, presented a completely different approach to synthesizing BAR (Birnberg, 2011). As research on the behavioral aspects of accounting had significantly expanded its scope and methodological "instrumentation" in the past years, Birnberg claimed that his proposal was intended to facilitate considering BAR wholistically rather than in parts such as financial accounting, managerial accounting, auditing etc., as has been the case in the past. He intended to support researchers in formulating their research objectives by simplifying comparisons with similar studies conducted in a different methodology or with studies of a similar topic but concerning different accounting subarea.

In 2017 three researchers from Indonesia made an attempt, although not very successful, to review and recapitulate BAR's areas of interest based on papers published in *Behavioral Research in Accounting* between 2005 and 2014 (Se Tin et al., 2017). The category titles they proposed seem so vague and ambiguous that it is difficult to deduce what kind of research should be assigned to them.

In recent years, there has been a noticeable trend for literature reviews to employ dedicated bibliometric analysis and science mapping software. However, in BAR's case, this trend is not yet clearly visible. The only study that uses such modern tools is the one by Singh from 2021 (Singh, 2021), which was devoted to behavioral finance and behavioral accounting together.

With the above in mind, it seems legitimate to examine the most recent directions of development of behavioral accounting. It might help to better outline its scope, framework or potential fruitful research areas. For this purpose,

bibliometric analysis can be helpful as it enables to capture of how the very concept of behavioral accounting functions in the literature nowadays. It can also provide some guidance for researchers on choosing keywords or formulating abstracts so that the results of their work are more clearly recognized as representatives of this field. From a practical perspective, our paper, by outlining the processes and key elements involved in the behavioral accounting environment and the identification of particularly important areas of its development, is expected to lead to the improvement of its rules, norms or best practices through better quality of accounting information and reduction of the impact of cognitive errors, so that business units function more efficiently not only in economical but also in a human sense.

Hence, this study, by employing bibliometric measures, especially science mapping, aims to identify literature streams embracing the notion of behavioral accounting and its links to other closely related topics covering the period from 2013 to 2022.

Method

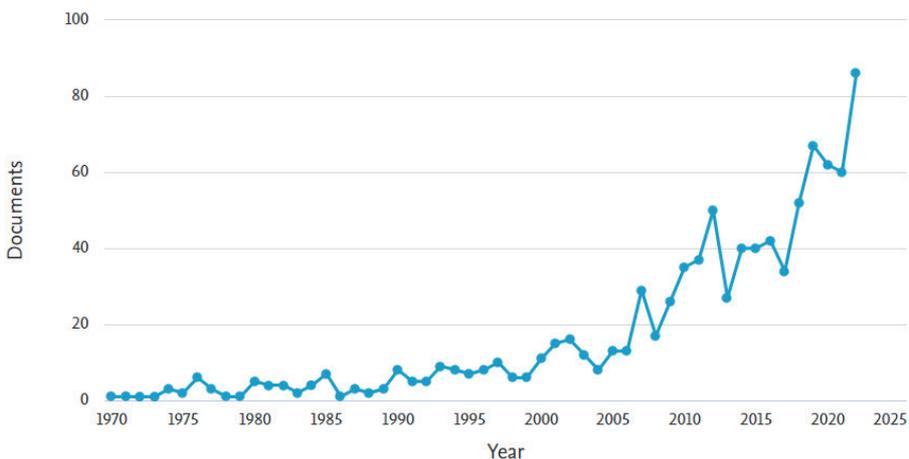
The study is based on the Scopus database for analysis. According to Okoli and Schabram (2010), the Scopus database is a multidisciplinary database suitable for researchers in the field of business and management. Moreover, as Oakleaf (2010) stated, Scopus includes documents indexed and classified by the Institute for Scientific Information. The authors read the abstracts of the papers separately, verifying their relevance to the topics covered in this study (Dal Mas et al., 2019; Biancone et al., 2022). The authors conducted the search in December 2022 using keywords “behavioral” and “accounting” based on the stream terms (DeZoort & Lord, 1997; Singh, 2021). The analysis gave a result of 5,776 documents. Additional selection parameters were introduced. Only articles in English in peer-reviewed journals were included in the sample (4,475 papers). To exclude numerous publications concerning medical or other nonrelated topics, the sample was limited to two sectors: “Business, Management and

Accounting” and “Economics, Econometrics and Finance” reaching 882 results. By selecting the last ten years of studies (from 2013 to 2022), 495 articles remained. A deeper content analysis based on the themes presented by titles and abstracts led to identifying a final list of 270 documents.

The reason behind the period of analysis (2013–2022) was twofold. First, Figure 1, based on the Scopus database, seems to confirm the thesis posed in the introduction about the growing popularity of the area, especially in the last ten years. The trend is clearly upward. Some decline occurred around 2020, which was probably due to the covid pandemic. It may have hindered academics from conducting research. Given that the experimental method dominates the field and experiments are challenging to conduct, not in direct contact, the research work may have slowed down a bit. Fortunately, the following years have seen the restoration of an upward trend again.

Another reason for the period selection was that the last review devoted to BAR ended with 2014 and concerned only one journal, i.e. “Behavioral Research in Accounting”. Thus, the sample interval supplements the analysis with the latest field output gathered from various journals and is long enough to capture the most current trends.

Figure 1. Annual scientific production



Source: own elaboration.

The data was analyzed using the Bibliometrix package from R software (Aria & Cuccurullo, 2017) and Biblioshiny a web-interface for bibliometrix (Campra et al., 2022). Further, VOSviewer cluster analysis was specified as suitable for bibliometric analysis (Secinaro et al., 2022). Those tools are designed explicitly for scientometrics’ quantitative research as they support various forms of analysis and facilitate the acquisition of the main data required from a classical bibliometric workflow (Donthu et al., 2021). The analysis included pointing out the most popular BAR outlets (journals) in recent years, the keyword frequency used by the authors to embed their works in certain framework, co-occurrence network, and the thematic maps. However, its main focus was on the conceptual structure.

Results

Table 1 presents basic information on the selected 270 articles published between 2013 and 2022 extracted from the Scopus database. They were published in 150 outlets, and each document was cited 12 times on average. Interestingly, the Keywords Plus parameter, which is the number of keywords frequently appearing in an article’s title, was almost 2,5 times less than the number of documents. It seems that searching by keywords rather than titles yields better results in finding relevant literature for further analysis in this field. As the characteristics in Table 1 indicate, the articles are mostly the result of the collaboration of at least two authors. Only 48 authors produced 55 papers only by themselves.

Table 1. Main characteristics of data

Parameter description	No.
Articles	270
Sources (Journals, Books, etc)	150
Annual Growth Rate %	13,53
Document Average Age	3,52
Average citations per doc	12,27

Parameter description	No.
References	17572
Keywords Plus (ID)	109
Author's Keywords (DE)	999
Authors	648
Authors of single-authored docs	48
Single-authored docs	55
Co-Authors per Doc	2,58
International co-authorships %	23,33

Source: own elaboration.

The results of behavioral accounting research are disseminated in many different journals, according to Table 2. There is no clear topic concentration in just a few outlets, except one. It is not surprising that Behavioral Research in Accounting (BRIA) leads the way in the ranking, as this is a journal strictly dedicated to such issues. Surprisingly, however, searching by keywords including terms such as “behavioral” and “accounting” turned up only 12 papers published therein during the last decade that passed inclusion criteria. Whereas BRIA publishes about 20 articles per year, it would be advisable to consider how to select bibliometric parameters for publications in this area to ensure greater consistency of search results.

Table 2. Most relevant sources

Top 25 journals	No. of articles
BEHAVIORAL RESEARCH IN ACCOUNTING	12
ACCOUNTING, AUDITING AND ACCOUNTABILITY JOURNAL	7
ACCOUNTING EDUCATION	6
JOURNAL OF BEHAVIORAL AND EXPERIMENTAL FINANCE	5
MEDITARI ACCOUNTANCY RESEARCH	5
REVIEW OF BEHAVIORAL FINANCE	5
REVISTA CONTABILIDADE E FINANÇAS	5
ACCOUNTING, ORGANIZATIONS AND SOCIETY	4
COGENT ECONOMICS AND FINANCE	4

Top 25 journals	No. of articles
EUROPEAN ACCOUNTING REVIEW	4
INTERNATIONAL JOURNAL OF SCIENTIFIC AND TECHNOLOGY RESEARCH	4
JOURNAL OF ACCOUNTING AND ORGANIZATIONAL CHANGE	4
JOURNAL OF APPLIED ACCOUNTING RESEARCH	4
JOURNAL OF BUSINESS ETHICS	4
JOURNAL OF INFORMATION SYSTEMS	4
JOURNAL OF MANAGEMENT CONTROL	4
MANAGERIAL AUDITING JOURNAL	4
ACCOUNTING	3
ACCOUNTING RESEARCH JOURNAL	3
ASIAN REVIEW OF ACCOUNTING	3
JOURNAL OF BANKING AND FINANCE	3
JOURNAL OF BEHAVIORAL FINANCE	3
JOURNAL OF ECONOMIC DYNAMICS AND CONTROL	3
MANAGEMENT ACCOUNTING RESEARCH	3
MANAGEMENT SCIENCE	3

Source: own elaboration.

Figure 2 shows the distribution frequency of articles dealing with behavioral accounting and related issues. A fairly stable growth is evident. Again BRIA is ahead of this expansion for the reasons already mentioned. Other journals essential for the development of the area include i.a.: “Accounting, Auditing And Accountability Journal”, “Accounting Education” or “Accounting, Organizations And Society”.

It may seem puzzling that “behavioral accounting” does not dominate among the keywords of the analyzed papers. It is only in fifth place in the row. While the apparent standout term is behavioral finance, which confirms the thesis of these areas’ high proximity and interpenetration. However, as Table 3 shows, the variety and dispersion of keywords is significant, which means that exploring and synthesizing the achievements of a field that does not use a unified conceptual framework might be quite challenging. The most used words characterize the main research topics addressed that could define the main discussion trends.

Behavioral finance refers to policies adopted or to be adopted in terms of finance. In particular, the use of foreign languages influences the perception of the financial terms “e.g., the fair value” in the IFRS, which conditions communication policies and language strategies (Hellmann & Tsunogay, 2021). The stream is associated with a broad debate concerning the choices of investors in the stock market, sometimes driven by rationality (asset-pricing models, accrual approach to obtain a positive sentiment of investors, investment choice linked to the bonus culture) (Park, 2018; Nasiri et al., 2021; Chen et al., 2017) and other times by irrational logic based instead on: overconfidence, regret aversion, anchoring biases, loss aversion and anchoring, representativeness, gambler’s fallacy, and mental accounting, mental accounting and availability biases (Isidore & Christie, 2018). Mental accounting refers to behavioral biases and investment attitudes that, during COVID-19, is conditioned by hindsight, overconfidence and self-attribution, representativeness, and anchoring to influence trading activity and recommendation intentions (Talwar et al., 2021). Mental accounting is also defined as a mental construct from which family financial decisions are derived based on some specific variables like financial attitude, risk attitude and financial knowledge, components of mental budgeting, current income, current assets and future income (Mahapatra & Mishra, 2020; Mahapatra et al., 2019). Accounting and behavioral accounting refers to the role of accounting and how accounting constructs can support other organizational activities (Pesämaa, 2017). Accounting behavior in trends is mainly associated with two main strands, the first related to the effect of performance analysis (Hariyanti et al., 2021) and the second related to the effect and perceived security is given internally and externally by assessments and the audit process (Brandon et al., 2014; Holt

& Loraas, 2019). Behavioral biases are oriented toward the investor's approach to making choices, and in particular, it is defined based on five identified personality typologies (Isidore & Arun, 2021). However, numerous secondary themes drive the current stream of research.

Table 3. Most frequent keywords

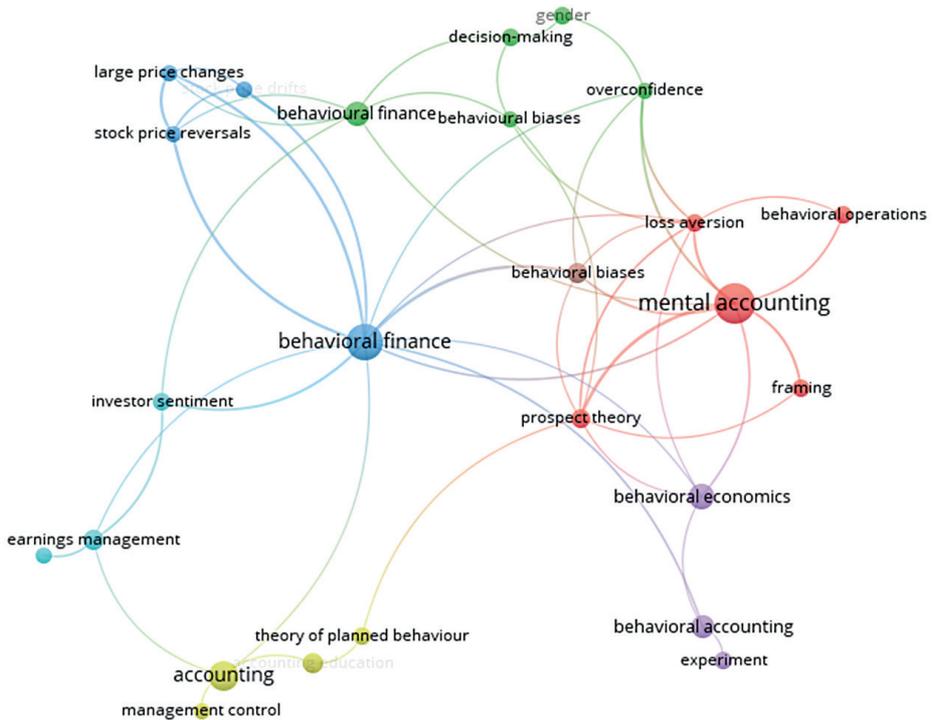
Keyword	Occurrences
behavioral finance	38
mental accounting	31
accounting	17
behavioral economics	13
behavioral accounting	10
accounting education	8
behavioral biases	8
covid-19	8
earnings management	8
big data	7
prospect theory	7
behavioral operations	6
decision-making	6
experiment	6
framing	6
gender	6
investor sentiment	6
loss aversion	6
theory of planned behaviour	6
behavioural biases	5
corporate governance	5
large price changes	5
management control	5
overconfidence	5
stock price drifts	5
stock price reversals	5

Source: own elaboration.

The above-listed keywords have been gathered in 7 clusters using VOSviewer software, as presented in Figure 3. These clusters are formed based on the keywords' co-occurrence. Two keywords co-occur if they both appear on the same author's keywords list (Bornmann et al., 2018). Thus, a stronger relationship is expected between keywords representing core issues in the subject area. The network of keywords' co-occurrence is therefore based on the assumption that keywords share a common bond when they co-occur. Such maps provide insight into the conceptual structure of a domain by examining how keywords are related to each other (Su & Lee, 2010).

In this case, behavioral finance comes to the fore, appearing in two clusters (blue and green) not only due to the spelling of the word “behavioral” or “behavioural” but also because of the different aspects covered therein. The blue cluster appears to be more concerned with stock pricing behaviours, while the green one focuses on biases associated with decision-making. The red cluster brings together a body of work based on the prospect theory, from which phenomena such as mental accounting, loss aversion or framing have emerged. The purple cluster, which contains behavioral accounting, lies a bit on the side-lines and seems to show an evolution of behavioral stream in economic sciences, which began with behavioral economics. However, a salient connection between behavioral accounting with behavioral finance is also evident. Such co-occurrences may indicate that the authors are reluctant to use “behavioral accounting” as a keyword for their papers but rather point to specific theories on which they base their research or even specific psychological phenomena.

Figure 3. Bibliometric map of keyword co-occurrences



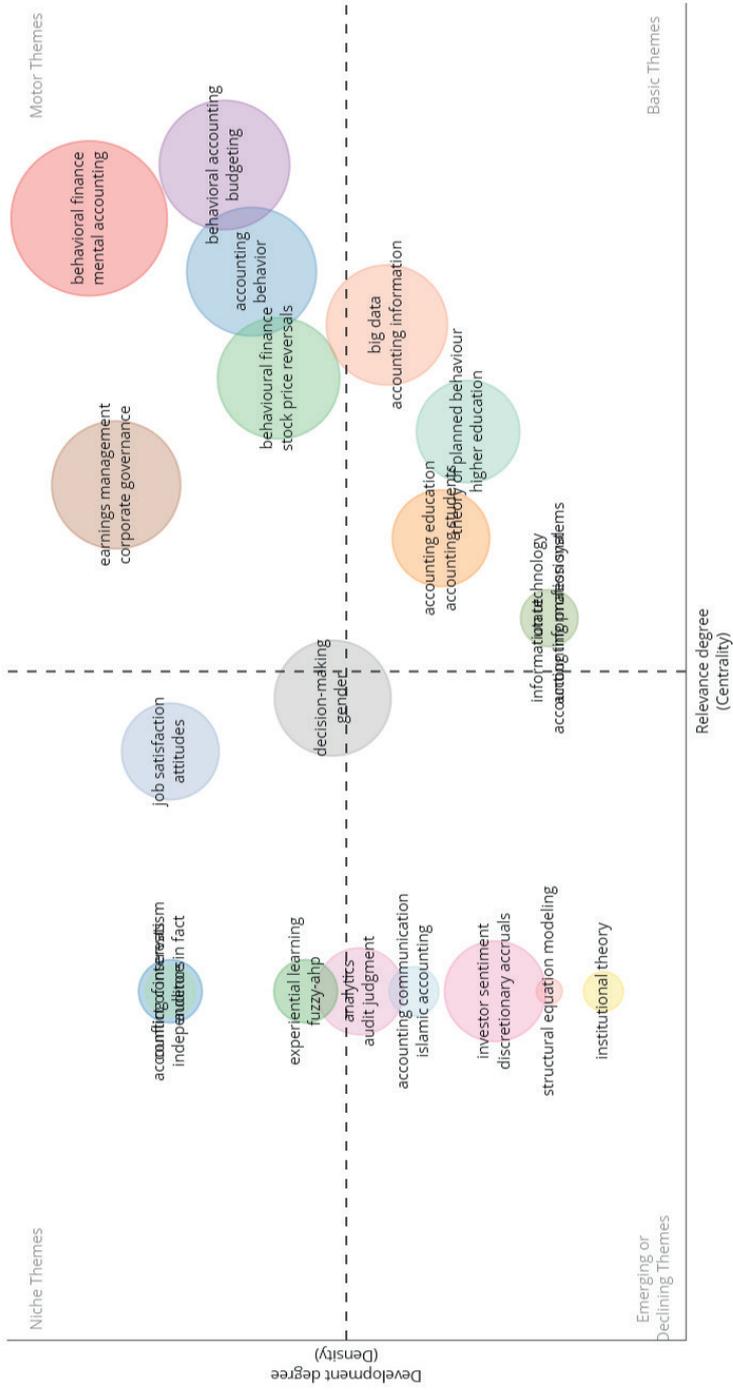
Source: own elaboration.

A valuable tool reflecting the evolution of certain topics over time is the thematic map. It provides insight into patterns, trends, seasonality and outliers in the given field that may assist researchers in identifying potential future developments (Aria & Cuccurullo, 2017). Interpretation of the thematic maps is very intuitive. Topics are grouped into four different quadrants based on their centrality (on the X-axis) and density (on the Y-axis). Centrality measures the level of linkages between themes, while density expresses the level of development in terms of cohesion within the cluster (Forliano et al., 2021). Depending on their location in a given quadrant, topics can be classified as motor, basic, niche or emerging/declining themes (Esfahani, 2019). According to Figure 4 behavioral accounting, together with behavioural research in accounting and budgeting, formed a cluster situated among motor themes. Behavioural finance and mental



accounting belong to the same quadrant. Another two driving clusters are those related to accounting information, earnings management and the application of accounting principles. It means that those topics are reasonably well-developed and crucial for structuring the research field. Issues that have a great potential to become basic or leading ones are those concerning fraud or whistleblowing. While accounting education or decision-making representing basic themes are very important but insufficiently exploited issues so far.

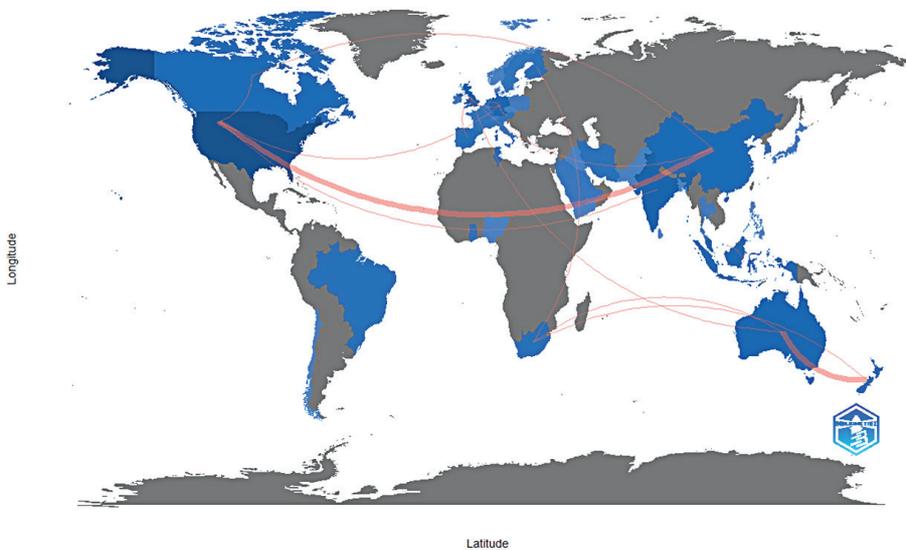
Figure 4. Thematic map



Source: own elaboration.

In the geographical distribution of papers prevail Anglo-Saxon countries, especially the USA, where behavioral accounting has its roots, with almost 50% of scientific production in the analyzed period. However, as the map indicates, behavioral accounting has also spread to other areas of the world, especially to Asia-Pacific region with India as a leader. Table 4 additionally provides the exact number of papers for a given country. Moreover, when it comes to cooperation between scientists from different regions, the strongest relationship is seen between the US and China, as well as Australia and New Zealand. India seems to be working mostly by its own efforts.

Figure 5. Geographical representation of scientific production and work collaboration



Source: own elaboration.

Table 4. Number of papers per country

Top 15 countries	No. of papers
USA	122
INDIA	42
UK	38
AUSTRALIA	33
GERMANY	29
INDONESIA	21
CHINA	18
MALAYSIA	18
CANADA	15
BRAZIL	14
NEW ZEALAND	14
TUNISIA	13
SPAIN	11
BELGIUM	10
GHANA	10
IRAN	10
PORTUGAL	10
SOUTH AFRICA	10
FRANCE	9
FINLAND	8
NETHERLANDS	8
ITALY	7
JORDAN	7

Source: own elaboration.

Conclusions

This study attempts to identify how the field of behavioral accounting functions nowadays in the subject literature utilizing bibliometric tools. Based on 270 documents selected in the period 2013–2022 from the Scopus database,

it presents the most common outlets where such publications appear, the most frequent keywords used by their authors and their country of origin, and also a thematic analysis of the domain indicating present areas of interest and fields worth further exploration. The analysis integrates the main trends and themes identified by Singh (2021).

The analysis showed that this domain is broadly dispersed. Publications appear in many journals whose main focus sometimes happens to be quite far from the psychological aspects of economic issues. Moreover, the papers often appear under titles that cannot be easily associated with the area of knowledge in question. The same is true for the keywords proposed by the authors to embed their work in a particular topic. There are many keywords in use, but very few include “behavioral” or “accounting”. This all may be the reason why bibliometric tools do not identify BAR as a distinct branch of knowledge. In the maps presented in this paper, BAR appears as a side subject area to behavioral economics or behavioral finance, proving that the field is at the beginning of forming its scientific identity.

There are several areas identified by science mapping tools that seem promising for future research. Regarding research topics, fraud detection, whistleblowing, and accounting education appear to be still very needy and promising areas for further exploration. Much common ground can be seen between them. It would be of benefit for future accounting professionals if their education included behavioral issues. Familiarizing them with specific psychological determinants could arm them with the proper tools to prevent i.a. fraud or other unethical practices in their professional life. As for the geographical aspect, it is evident that this area of knowledge is not yet well developed in Europe. Thus, it seems that it would be beneficial for scholars from the “old continent” to strengthen cooperation with, for example, researchers from the US, who already have a pretty long experience conducting research in this area. Behavioral accounting is developing worldwide, and the dynamics of this development have accelerated significantly in recent years. However, the lack of clear boundaries and, thus a significant degree of dispersion make it challenging to assess its accurate dimensions. The number of works may be significantly underestimated as authors very often do not identify their works as behavioral accounting but

rather as finance, management, auditing etc. This fact can be deemed a limitation of this study but also a guide for researchers to consider including the term “behavioral accounting” in the keywords list of their papers so that the search criteria become more evident and their results more accurate.

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Sustainability Disclosure in Social Media – Substitutionary or Complementary to Traditional Reporting?

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ABSTRACT

Objective: This study examines sustainability disclosure by 50 British companies from FTSE 100 and compares reporting via traditional sources and on Twitter by indicating whether the content in two various disclosure channels is of substitutionary or complementary nature.

Methodology: A content analysis on more than 20,000 tweets was performed to examine sustainability disclosure practices which were compared with Bloomberg ESG scores for each studied company.

Findings: On the general level of sustainability division into three pillars (Environment, Social and Governance), it can be observed that social media reporting provides complementary information. Whereas, the disclosure of environmental issues via traditional sources was relatively poor, the reporting of environmental information in social media performed best. However, with the division on ESG sub-pillars, the picture is not that clear. Most of the poorly performed ESG sub-pillars in traditional reporting, were also poorly reported in social media.

Value Added: This article is a response to the call for studies on non-financial disclosure via social media, which is strongly highlighted in the recent literature concerning future research. Additionally, a comparative analysis with the reporting by traditional, well-studied channels was performed.

Recommendations: This study offers an understanding of the British companies' corporate practices that refer to sustainability disclosure by traditional channels and via social media. Hence, it has implications for organizations in the creation and use of communication channels when developing a dialogue with stakeholders on topics regarding sustainability.

Key words: sustainability, ESG, disclosure, social media, Twitter

JEL codes: G34

Introduction

In the contemporary business environment, companies are increasingly performing activities that shift from purely income maximization to ethical and sustainability issues (Nirino et al., 2019). Firms that consider the non-financial aspects of the business reduce market risk and mitigate the information asymmetry faced by lenders and investors in the financial market (Perrini et al., 2011). The rising awareness of stakeholders towards health, food safety, and the environment leads to the development of new strategies that include market competitiveness, sustainability, and ethics (Lazarides & Goula, 2018). This evolving firm's strategy is perceived as an important factor for its long-term success in terms of competitive advantage, risk management, and sustainability. Reporting sustainability has become crucial for companies, as it creates a better image of the processes inside the organizations and thus provides a space for value growth. By providing economic, environmental, and social information, the organization may communicate with various potential parties, including suppliers, creditors, activist groups, the government, the media, customers, and the general public (Saxton et al., 2019). Traditionally, corporate annual reports were considered the primary source for communicating organizational performance to their stakeholders (Hadro et al., 2021). However, traditional reporting via e.g. annual reports has certain shortcomings, such as lack of interactivity and time lag of information disclosed (Fijałkowska et al., 2019). Additionally, the rapid transformation in technologies and forces of mass communication, together with digitization, provide challenges and opportunities for companies concerning information disclosure to key stakeholders. Digitization has fundamentally changed the traditional media landscape and altered how organizations and their actions are publicly evaluated (Vogler, 2020). Consequently, periodic and formalized communication seems to be losing a reason to be (Piber et al., 2019). Especially, in the last decades, social media has disrupted the firms' reporting field by providing a more dynamic and interactive public space (Neu et al., 2020). Social media offers a platform for diffused stakeholders to interact with companies and engage in two-way communication. As argued by Ndou et al. (2018), websites and social media generate massive, variable,

and valuable amounts of data from a variety of sources (Secundo et al., 2017). As a result, new research challenges emerged to investigate the implications of social media platforms for company communications and they refer also to the disclosure of corporate sustainability actions (Bryl et al., 2022a).

Therefore, this study attempts to compare reporting via traditional sources and social media to identify if the information disclosed is similar or different. In this sense, the paper determines if social media disclosure on sustainability is complementary or substitutionary to traditional reporting. The study focuses on large business companies, as they are the forerunners of social media adoption for corporate purposes. To answer the research question a sample of 20,247 messages (in form of tweets) sent throughout 2021 by the 50 Twitter accounts of the largest 50 firms in the FTSE 100 index was examined. Consequently, this study aims to fill two research gaps in the literature: first to identify the main topics referring to sustainability disclosed via social media in the context of a developed economy, and second to compare the disclosed content with traditional reporting. To the best of our knowledge, this topic has not yet been systematically investigated, although several studies have emerged.

The findings may help understand what sustainability topics companies perceive as most important to be communicated to stakeholders by two different reporting channels. The findings may have implications for organizations in the creation and use of communication channels.

The structure of the paper is as follows: first, a literature review concerning social media and sustainability was performed; second, the main theoretical perspectives that provide grounds for the development of research questions and empirical analysis were explained. In the following section, the methodology of research was developed along with the discussion of the results. Finally, conclusions and practical implications, followed by the limitations and future research avenues were presented.

Literature review and research questions development

Theoretical background of sustainability disclosure

The origins of corporate disclosure practices can be anchored in four theories: stakeholder theory (Freeman, 1984), agency theory, signaling theory, and legitimacy theory (Cho et al., 2015). Freeman (1984) defines a stakeholder as “a person or group that can affect or is affected by the achievement of the organization’s objectives, including shareholders, creditors, suppliers, employees, and government as well”. The stakeholder theory states that organizations are responsible for their activities due to interest-based, rights-based, and duty-based accountabilities (Scaltrito, 2016). An interest-based approach stresses the effects of organizational activities, the rights-based analysis calls for fair distribution of resources and opportunities, while the duty-based approach looks at organizational responsibilities to stakeholders. Ultimately, the stakeholder theory underlines that companies should attempt to fulfill stakeholders’ demands, which, at least in the long term, leads to higher economic profits (Freeman, 1999). Jones (1995) argues that trusting and cooperative relationships with stakeholders help firms to achieve a competitive advantage over companies with a low level of stakeholder focus. However, Bauer and Hann (2010) state that environmental externalities may lead to various corporate concerns. Consequently, companies involved in environmental issues can be the subject of costly penalties leading to negative reactions from stakeholders which ultimately affects their default risk. Therefore, the stakeholder theory may imply that the greater extent of corporate responsibility activities the lower cost of capital (Bryl & Fijałkowska, 2020).

The agency theory investigates the problems of moral hazard and adverse selection deriving from the different interests between agent and principal which leads to information asymmetry (Firth, 1980; Chow & Wong-Boren, 1987). Diamond and Verrecchia (1991) introduced a theoretical model showing that voluntary disclosure decreases the information asymmetry among

investors. Corporate reporting contributes to the increase of liquidity of the market, which leads to capital cost reduction since liquidity is perceived as a function of information asymmetry (Glosten & Milgrom, 1985). While firms disclose more about their activity, additional reporting on chosen corporate issues may contribute to limiting the information gap between the two parties, which ultimately reduces the shareholders' uncertainty and reduction of cost of capital (Watson et al., 2002).

The signaling theory states that firms are enhanced to disclose more information as it not only leads to the information asymmetry reduction but also shows (signals) to outsiders that the firm performs better in comparison to its market competitors (Scaltrito, 2016). Consequently, better performance leads to better perception by the financial markets and thus lower risk. According to the signaling theory, corporate non-financial disclosure expands the spectrum of recipients of information, making the intended audiences for the CSR signals, customers, shareholders, influencers, advocates, media, NGOs, policymakers, governmental organizations, and citizens (Connelly et al., 2011; Du et al., 2010). Similarly, better non-financial reporting allows firms to increase the plurality of stakeholders, ranging from customers and employees to suppliers and the government (Raimo et al., 2019; Vitolla et al., 2019). As predicted by the signaling theory, in a capital market context, disclosures are important for reducing information asymmetry, lowering the cost of capital, and limiting the risk of adverse selection (De Villiers & van Staden, 2011).

The legitimacy theory suggests that corporate disclosure legitimizes a firm's behaviour (Rodrigue et al., 2015; Diouf & Boiral, 2017), as there is some form "social contract" created between the company and society. Consequently, an obligation emerges for the the firm to act in accordance with a set of accepted values, principles, and standards (Deegan, 2006), so that the company does not lose its legitimacy.

In this study, the Author also identifies the theory of media richness (Daft & Lengel, 1986) that may serve as an explanation for social media disclosure. The main assumption of that theory lies in the fact that media are different in the "richness" of their "ability of information to change understanding within a time interval" (Daft & Lengel, 1986, p. 560). Thus companies could boost

performance by linking media channels with the current disclosure needs. It should be noted that media richness foundations have also been applied in research on corporate social and environmental reporting (Cho et al., 2009).

Social media as a new way of sustainability reporting

The annual report in the “traditional” (paper or pdf) form has long outlived themselves as the best source of corporate disclosure (Cuzzo et al., 2017). It is both backward-looking and a form of one-way communication; therefore, it features two significant failures in today’s forward-focused and interactive discourse mediums (Dumay, 2016). Moreover, the information published in “traditional” annual reports is often delivered to stakeholders with a significant time lag. Therefore, it is argued that research on sustainability reporting should adopt a more innovative perspective by investigating modern tools for disclosure, such as e.g. social media platforms. Social media is a useful, informative, and rich channel of communication between organizations and stakeholders. Social media has become an important element of companies’ internal and external communication strategies (Zhang et al., 2020). Communication between a company and its stakeholders becomes more dialogic on social media, as it allows citizens to praise, engage, ask, and criticize. Social media is a highly interactive and publicly visible forum (Colleoni, 2013). With the emergence of social media, stakeholders can articulate their opinions about organizations without passing through news media gatekeepers (Etter et al., 2019). Social media has the potential to “change the dynamics of corporate–society relations” (Whelan et al., 2013, p. 778) and offers a way to preserve and foster relationships with stakeholders (Castello et al., 2016). Therefore, companies use social media to demonstrate that they are responsive (Fukukawa, 2019) to their stakeholders. In this way, they legitimize their actions and strive to be transparent and accountable.

Research show that firms use social media to create discrete visual and textual “micro-reports” on their CSR-related activities. As, one of the greatest

advantage of social media is the potential of two-way communication with, several studies have focused on sustainability, including environmental and corporate social responsibility disclosure. As a result, some firms for over a decade have experimented with social media platforms to increase stakeholders' engagement in dialogues about these topics (Colleoni, 2013; Lee et al., 2013; Okazaki et al., 2019, Castelló et al., 2016; Orazi et al., 2017, Saxton et al., 2019; Yang et al., 2020). However, still a relatively small number of companies use social media to engage stakeholders in CSR activism (Lodhia et al., 2020; Manetti & Bellucci, 2016). Stakeholders perceive disclosure in social media as a marketing practice (Colleoni, 2013), and the interactivity of messages is low (Suárez-Rico et al., 2019). Existing studies concentrate on the analysis of sustainability disclosure either in social media only or in other channels only. There is a lack of a holistic approach encompassing all potential sources of sustainability reporting that would include comparative analysis, as it has been performed with reference to the studies on financial disclosure. For example, Prokofieva (2015), on the sample of Australian Stock Exchange companies, showed that firms publish corporate information on Twitter when it is already disclosed in other channels (e.g., corporate websites). Blankespoor et al. (2014) found that high tech companies provide links of earnings press releases on Twitter. Jung et al. (2018) stated that S&P companies are less likely to employ Twitter for disseminating information on earnings when the news is bad. Similarly, Crowley et al. (2018) argued that companies use Twitter more if they anticipate that the information already disclosed elsewhere (e.g., SEC filings, press release, or conference calls) has a significant positive or negative impact, but tweet less if the information provides a neutral effect. This goes partially in line with the findings of Cade (2018) who determined that firms can use Twitter to mitigate the impact of negative public reactions to potential earnings management by pointing out more positive aspects of their financial performance. To summarize, existing studies focus on trying to find the link between the corporate disclosure practices in social media and other channels with relation to financial disclosure. As a result, to the best of the Author's knowledge, there is no study performing a comparative analysis of the content of sustainability reporting via

social media and other channels, and that creates a research gap that this study attempts to address.

Considering a theoretical framework and existing empirical studies the following research question was formulated:

RQ: Does social media sustainability reporting play a substitutionary or complementary role to traditional disclosure sources?

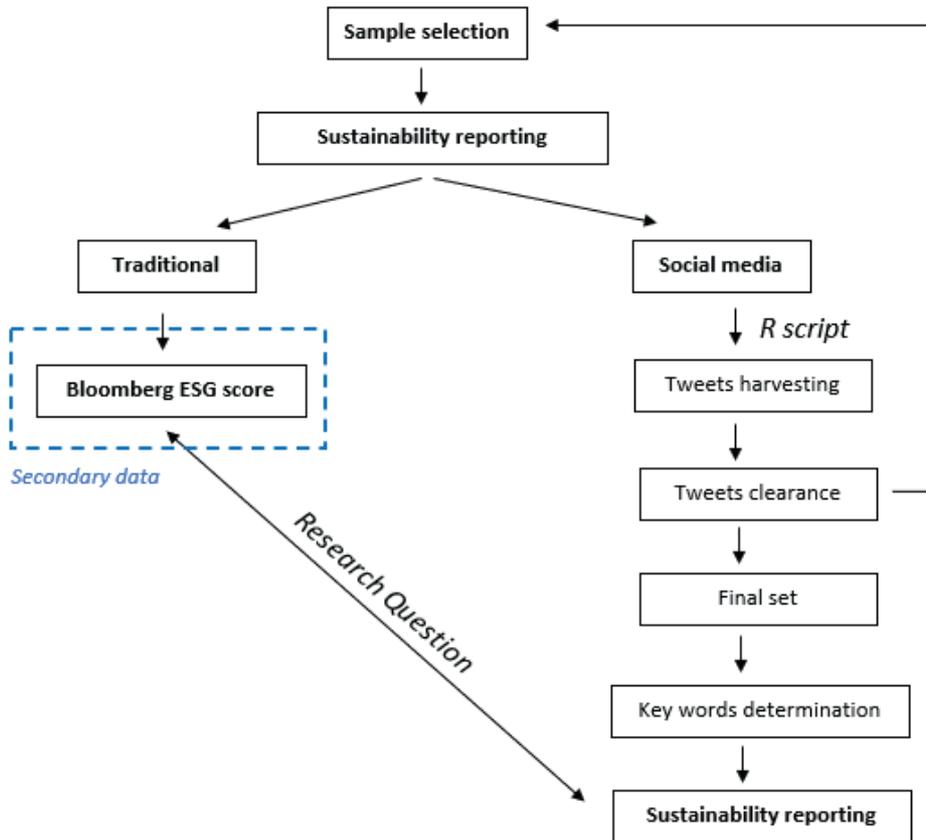
Methodology

Sample and data

To analyze the main elements of sustainability that companies disclose on social media the research was concentrated on the top 50 companies from the FTSE 100 index for the year 2021. The investigation involved the largest British business corporations based on their market capitalization in descending order without focusing on any specific industry. Twitter was employed as a social media platform to study the corporate disclosure practices on sustainability. Twitter is one of the leading social media platforms used by firms (Tao & Wilson, 2015). Additionally, in 2013 Twitter along with Facebook were approved by SEC (Securities and Exchange Commission) as formal corporate disclosure outlets (Lijun et al., 2019). A study by Bryl (2021) indicated that 75% of the 100 global corporations have at least one official corporate account on Twitter. In the proposed study only those companies that had Twitter accounts throughout 2021 were selected. The Twitter accounts of each company were identified and manually the data was checked to eliminate false corporate profiles. This study encompassed only official English-language profiles based on the firm's name and excluded sub-brands. In the case of numerous official profiles, the one with the greatest number of tweets was always chosen. Additionally, as the study progressed, companies having a low level of Twitter activity were excluded (less than 50 tweets in 2021).

To perform a comparative study of sustainability disclosure, a conceptual framework was developed (Figure 1).

Figure 1. Research design framework



Source: own work.

First, the traditional reporting outcomes were obtained. The Bloomberg ESG score was employed as a tool to gather data and analysis of sustainability corporate actions for the given company. The Bloomberg ESG score is a valid source of information on sustainability. The ESG data are captured only from direct (primary) sources in order to ensure accuracy and consistency with original corporate information. These sources include

sustainability reports, annual filings, proxy statements, corporate governance reports, supplemental releases, and company websites (Bloomberg, 2020). They are published for every year and provide information on three sustainability pillars: Environment (E), Social (S), and Governance (G) with the latter divided into sub-pillars and sub-indices (for details see the attachment). It was assumed that the reporting of sustainability by Bloomberg is considered as the traditional one, as it does not take into account information disclosed on social media. This nomenclature may, however, confuse, as under the Bloomberg disclosure there is also information gathered from corporate websites which are not necessarily considered as a traditional way of reporting. Nevertheless, for the needs of this study, Bloomberg scores are considered traditional ones.

To pursue the study on social media disclosure, first, a database of tweets was created. To collect data, a dedicated R script (Rtweet) was used that employed the official Twitter API to download tweets from corporate English profiles for the entire year 2021 (20,247) (Table 1). To determine the sustainability of content in tweets, a content analysis based on the keyword counts method was employed, followed by the study by Bryl et. al (2022b). A single tweet containing only text was defined as a unit of analysis, based on Krippendorff's (2004) rules for content analysis. Tweets were cleaned from pictures, videos, and/or external links to focus only on the textual content posted by companies. The keywords/keyphrases approach was used to determine the disclosure of sustainability. Keywords/keyphrases were defined as either a separate word (carbon), an abbreviation (GHG), or a phrase (climate change) multiplied by various lingual expression forms. To identify the sustainability keywords and to enable the comparability with the Bloomberg score, an original set of keywords was created based on the topics identified by Bloomberg. The total number of keywords was 205. An Excel spreadsheet was developed containing a set of tweets for each company. Excel formulas automated the process of investigating tweets for keywords, which was supported by a random manual double-check. Later, industry analysis was performed to look for differences in the type and content of sustainability disclosure. Table I shows descriptive statistics of the studied sample.

Table 1. Descriptive statistics of the studied sample

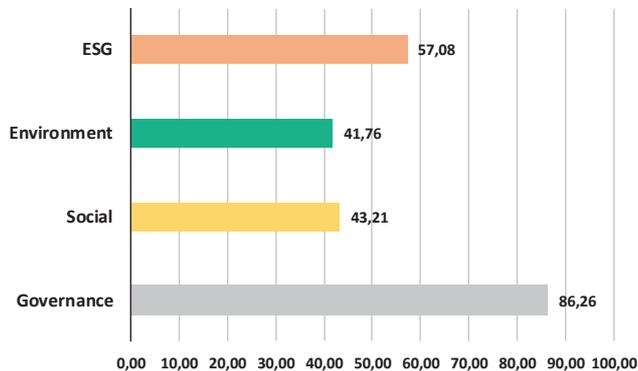
No. of companies	50
National context	British
Tweets	20,247
Mean	532.8
Median	430.5
Min	58
Max	1,686

Source: own elaboration.

Results and discussion

In terms of traditional disclosure, it was found that in general the extent and quality of ESG disclosure are moderate, as the average score in the studied sample of firms amounted to 57,1 (out of 100). However, the pillar referring to Governance performed exceptionally, since its overall score was 86,3 (out of 100) which suggests a remarkable effort of the British companies in the field of Governance reporting. The general breakdown of the ESG pillars disclosure depicts the figure below.

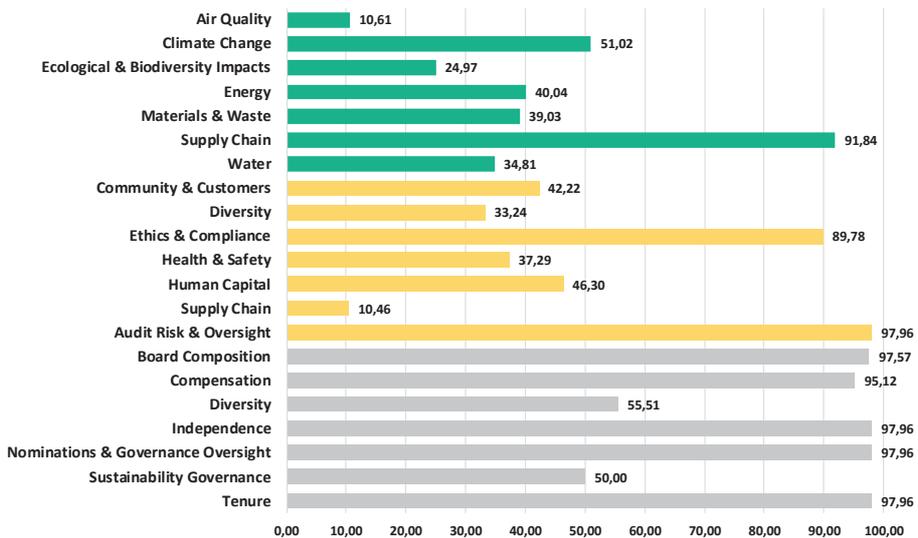
Figure 2. Disclosure of ESG pillars breakdown via traditional sources



Source: own work.

The Environment and Social pillars performed similarly below average with a slightly better score for the Social pillar (43,2 vs. 41,8). Nevertheless reporting in these fields should be perceived as insufficient. A closer look at ESG sub-categories provides a broader picture (Figure 3).

Figure 3. ESG sub-categories breakdown



Source: own work.

As the information referring to the Governance pillar was found to be the best out of all three, the Governance sub-categories also provided a satisfactory score. Only Diversity and Sustainability Governance underperformed in relation to the others. However, British companies reported much worse in the other sub-categories. The most neglected sub-categories in the corporate disclosure practices were: Air quality, Supply Chain (under the Social pillar), and Ecological & Biodiversity Impacts. Surprisingly, disclosure on Supply Chain under the Social pillar was much worse than reporting on Supply Chain under the Environment pillar. This phenomenon can be easily explained, since, although the ESG sub-category is the same, it does not mean its information content is similar. In fact, the suggested scope of information differs

significantly, however, the sub-category name may be misleading (see Bloomberg ESG score in Appendix).

In terms of frequency in the studied group, very rare cases were found where companies did not disclose any information concerning a given ESG subcategory. The only exception was the sub-category referring to Air quality and Ecological & Biodiversity Impacts, which surprisingly were not reported at all by 76 and 30 percent of the companies, respectively. In the case of the other ESG sub-pillars, the reporting frequency can be assessed as satisfactory (Table 2).

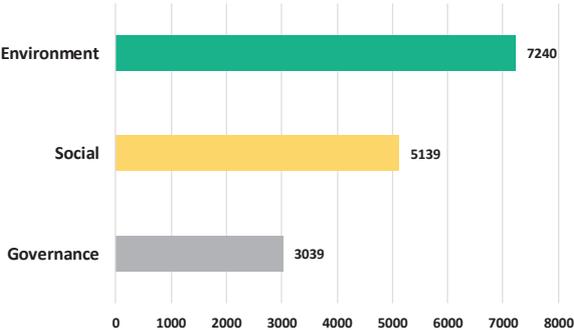
Table 2. Frequency of ESG sub-category disclosure via traditional sources

ESG sub-category	No./Percent of companies with no disclosure
Air Quality	38 (76%)
Climate Change	1 (2%)
Ecological & Biodiversity Impacts	15 (30%)
Energy	1 (2%)
Materials & Waste	2 (4%)
Supply Chain	4 (8%)
Water	4 (8%)
Community & Customers	1 (2%)
Diversity	1 (2%)
Ethics & Compliance	1 (2%)
Health & Safety	1 (2%)
Human Capital	1 (2%)
Supply Chain	1 (2%)
Audit Risk & Oversight	1 (2%)
Board Composition	1 (2%)
Compensation	1 (2%)
Diversity	1 (2%)
Independence	1 (2%)
Nominations & Governance Oversight	1 (2%)
Sustainability Governance	8 (16%)
Tenure	1 (2%)

Source: own elaboration.

Concerning social media reporting, an adverse phenomenon was identified. Companies reported mostly on issues regarding the Environment, whereas the Governance information was disclosed the least often (differently to reporting via traditional sources).

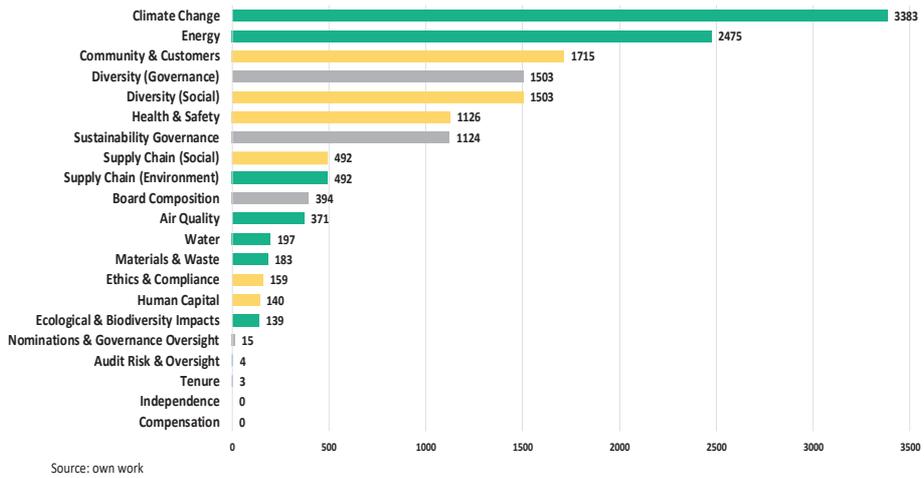
Figure 4. Disclosure of ESG pillars breakdown via Twitter



Source: own work.

With regard to ESG sub-categories, Twitter content is mainly concentrated on the topics of climate change and energy. These two topics accounted for 38 percent of all ESG mentions via tweets. What is interesting is that the studied British companies did not disclose any information regarding two Governance pillars, which are Independence and Compensation (Figure 5).

Figure 5. ESG sub-categories breakdown



Source: own work.

In general, reporting on ESG on Twitter was less frequent than via traditional sources. This is partly explained by the nature of communication through tweets, which are short messages and thus usually do not contain much information. Therefore, the frequency in the case of certain ESG sub-categories was dramatically low, and even the previously mentioned Independence and Compensation sub-categories were not disclosed by any single studied company. Additionally, only two companies were disclosing on the Tenure ESG sub-category.

Table 3. Frequency of ESG sub-category disclosure via Twitter

ESG sub-category	No./Percent of companies with no disclosure
Air Quality	18 (36%)
Climate Change	14 (28%)
Ecological & Biodiversity Impacts	24 (48%)
Energy	16 (32%)
Materials & Waste	25 (50%)
Supply Chain	20 (40%)
Water	17 (34%)
Community & Customers	14 (28%)

ESG sub-category	No./Percent of companies with no disclosure
Diversity	16 (32%)
Ethics & Compliance	38 (76%)
Health & Safety	15 (30%)
Human Capital	26 (52%)
Supply Chain	23 (46%)
Audit Risk & Oversight	47 (94%)
Board Composition	15 (30%)
Compensation	50 (100%)
Diversity	19 (38%)
Independence	50 (100%)
Nominations & Governance Oversight	46 (92%)
Sustainability Governance	15 (30%)
Tenure	48 (96%)

Source: own elaboration.

The analysis revealed that the answer to the research question is ambiguous. On one hand, social media omitted the reporting in the Governance field which can be explained by the fact that these pillars and related sub-pillars were relatively well disclosed by traditional sources. Additionally, the best-reported sub-pillars via Twitter (Climate Change and Energy) performed on average in traditional reporting channels, which may justify, to some extent, the complementary role of social media in the process of sustainability disclosure. However, on the other hand, the least disclosed sub-pillars, which were Supply Chain (Social), Air quality and Ecological & Biodiversity Impacts, were also poorly reported via Twitter. In this sense, complementarity did not take place.

Conclusions

This paper analyzed the sustainability disclosure practices performed via traditional sources and social media (Twitter) by British publicly-listed companies. Additionally,

the aim was to compare the quality and extent of reporting in each source to determine if the corporate disclosure on sustainability differs with regard to the source. As a result, valuable insights into the studied field can be introduced, although the final result is not unambiguous. First, on the general level of sustainability divided into three pillars (Environment, Social and Governance), it can be observed that social media reporting provides complementary information. Whereas, the disclosure of environmental issues via traditional sources was relatively poor, the reporting of environmental information in social media performed best. However, with the division into ESG sub-pillars, the picture is not that clear. Most of the poorly performed ESG sub-pillars in traditional reporting were also poorly reported in social media.

The proposed paper has several practical implications. First, it fosters further development of strategic thinking about the role of social media reporting in sustainability. Second, the paper provides a brief outlook on how companies manage the flow of information to stakeholders. Third, conclusions based on quantitative analysis (such as e.g., frequency of disclosure) may serve as practical guidelines for enterprises considering their communication strategies with stakeholders. The study has several limitations. These are e.g., the sample studied is fairly small, the study covers one year only, and the lack of cross-country comparisons. Future studies should address these shortcomings.

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Forecasting Prices of Shares Listed on the Warsaw Stock Exchange Using Machine Learning

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ABSTRACT

Objective: The technology developing before our eyes is entering many areas of life and has an increasing influence on shaping human behavior. Undoubtedly, it can be stated that one such area is trading on stock exchanges and other markets that offer investors the opportunity to allocate their capital. Thanks to widespread access to the Internet and the computing capabilities of computers used in the daily activities of investors, the nature of their working has changed significantly, compared to what we observed even 10–15 years ago. At present, stock exchange orders may be placed in person using various types of brokerage investment accounts, which allow the investor to view real-time quotations which opens up a whole new range of opportunities for investors. Its skillful application during the stock market game can positively influence a player's investment performance. Machine learning is a branch of artificial intelligence and computer science that focuses on using data and algorithms to solve decision-making problems based on large amounts of information. In machine learning, algorithms find patterns and relationships in large data sets and make the best decisions and predictions based on this analysis.

Methodology: The main objective of this paper is to investigate and evaluate the applicability of machine learning for investment decisions in equity markets. The analysis undertaken focuses on so-called day-trading, i.e. investing for very short periods of time, often involving only a single trading session. The hypothesis adopted is that the use of machine learning can contribute to a positive return for a stock market player making short-term investments.

Findings: This paper uses the Azure Microsoft Machine Learning Studio tool to enable machine learning-based calculations. It is a widely available cloud computing platform that provides an investor interested in creating a model and testing it. The calculations were made according to two schemes. The first involves teaching the model by taking 50% of the companies randomly selected from all companies, while the second involves teaching the model by taking 80% of the companies randomly selected from all companies.

Value Added: The results from the study indicate that investors can use machine learning to earn returns that are attractive to them. Depending on the teaching model (50% or 80% companies), daily returns can range from 1.07% to even 4.23%.

Recommendations: The results obtained offer investors the prospect of using the method presented in the article in their capital management strategies, which of course requires them to adapt the techniques used so far to the specifics of machine learning. However, it is necessary to note that the presented method requires that each time the data on which the forecast was made be updated..Further research is needed to determine the impact of the number of companies on the effectiveness of the learning process.

Key words: stock market, investment strategies, machine learning

JEL codes: E 22, E 44, G 11, G 31

Introduction

The real-time quotations allow the player to view real-time stock quotes with various technical indicators plotted on the chart, or to view parallel quotes in different time frames (daily, hourly or in any minute intervals) and the option to view the order book. Another important aspect is the almost immediate access of investors to the news that may influence the course of quotations and stock exchange volatility. This can also have the negative effect of overloading these investors with market information, which in turn can have a negative impact on their cool heads and emotional composure when making transactions. The solution to these problems may turn out to be the use of such tools, which will eliminate the negative influence of large amounts of information and will remove, of course only to a limited extent, the negative influence of emotions on the decision-making process.



An example of such tools can be the use of so-called machine learning, which assists the investor in the analysis of information coming from the market, which will form the basis for assessing the possibility of taking a position in the market. Thanks to the use of this tool, the investor may receive a valuable instrument for managing money and financial instruments, which differs significantly from technical, fundamental or portfolio analysis. The idea of using machine learning in stock exchange trading may boil down to making transactions in very short time horizons covering the duration of a single stock exchange session.

Keeping the above considerations in mind, the purpose of this study is to investigate and evaluate the applicability of machine learning for making investment decisions on stock market. The study hypothesizes that the use of machine learning can contribute to a positive rate of return for a stock market player making short-term investments. The rationale behind the analysis undertaken in this way is that within the scope of this article it is difficult to find academic studies that examine this issue in a comprehensive manner and that consider the application of machine learning to short-term investment decisions. This article contributes to closing the research gap concerning the investigated topic.

Additionally, an important aspect that one should pay attention to is the so-called “market efficiency”, i.e., the assumption that it is impossible to obtain a “better-than-market” rate of return by relying on historical information when making decisions to buy and sell financial instruments. In this paper, the authors undertake to evaluate the effectiveness of a machine learning-based investment method in the context of the possibility of obtaining positive rates of return, rather than comparing these rates with control strategies, as is done when studying market efficiency.

Literature review

Stock markets have been analyzed for their efficiency many times before, but the framing of these studies has been of a different nature than in this paper.

A number of studies are relevant to this issue. In terms of efficiency, the first one was related to the evaluation of the use of so-called technical tools (averages and oscillators), and the results obtained indicated that these methods do not give above-average and, importantly, statistically significant rates of return (Czekaj et al., 2001). The other study (Szyszka, 2003) noted that the stock market in Poland was not efficient in its initial phase of development. Also in the subsequent years of the functioning the stock market, there were no grounds to reject the low information efficiency on this market.

Investors, practically from the very beginning of trading on stock exchanges, have been trying to figure out the mechanism by which prices move in such and such a way. Over the years many methods, tools or techniques have been developed that allow taking investment decisions in a “rational” way. It is worth paying attention to this rationality, because on the grounds of economic sciences and psychology man tries to act rationally, although the reality shows unequivocally that not all behaviors meet this criterion.

Over the years many methods have been developed to facilitate investment decisions, among the most popular are fundamental, technical and portfolio analysis. Fundamental analysis seems to be a relatively good solution for investors prepared for quite a long-time horizon of their transactions. Fundamental analysis examines phenomena characterized by duration counted in months, quarters and even years (Tarczyński, 2001).

Technical analysis, another approach facilitating decision processes, is completely unable to keep track of the dozens or even hundreds of pieces of information that constantly flow in from the market, and that can have an impact on the quotes and focuses only on observation of quotation charts, which are supposed to be the basis for forecasting the direction of price changes. Although computer programs and literature provide investors with dozens of indicators, in general, they can be divided into three basic categories (Elder, 1993):

- Trend indicators – the most important of which are moving averages and Moving Average Convergence / Divergence (MACD),
- Oscillators – which include the Relative Strength Index (RSI), Momentum, and Stochastic Oscillator,

- Sentiment indicators – to gauge how optimistic or pessimistic the market crowd is.

Technical analysis is based on several important assumptions:

- the price of a financial instrument discounts everything, i.e., all relevant information about a given stock is contained in it, therefore there is no point in analyzing dozens of pieces of information about, for example, the company which is the subject of our investment,
- history likes to repeat itself, i.e., some characteristic mutual arrangements of prices have a feature of periodical appearance on the chart of the stock,
- the prices move in trends, which means that the price of the financial instrument that interests us may in a certain time horizon have an upward or downward trend or move within the so-called horizon (Murphy, 2019).

Portfolio analysis, the third method supporting decision processes, is a method based on determining risk based on historical data concerning quotations and rates of return in order to minimize the risk of transactions when building the portfolio.

The problem associated with the use of technical analysis boils down to the fact that it is not possible to obtain an accurate forecast of share prices. Depending on the research period, the market situation and the approach to decision-making used, the obtained results may indicate both the usefulness and uselessness of technical analysis (Anghel, 2015). In view of the foregoing, the development of modern technology has created new opportunities to solve existing problems in many areas. One of these is the ability to make more accurate forecasts of the prices of financial instruments, which can be particularly important for investors.

In many fields of science, as well as in everyday life, the term “artificial intelligence” is becoming more and more common, which is a very broad term describing technology that enables intelligent responses to external stimuli

(Stephenson, 2020). The term “machine learning”, on the other hand, can refer to a technology by which a computer program can improve its performance, even without the input of a programmer. Machine learning algorithms can process very large amounts of training data, and artificial neural networks are already well understood and used in this area (Stephenson, 2020). Neural networks are information processing systems, in the structure of which one can find a kind of mapping of elements of the biological nervous system. Nowadays, the application of neural networks is very wide, and they are used, among others, in stock market forecasting, medical and biological research, data analysis and economic forecasting (Rutkowski, 2005).

Although the terms artificial intelligence and machine learning are often used interchangeably their meanings are slightly different. In the first case, we have a situation where the system will try to mimic human intelligence in solving complex problems. This involves the ability to recognize specific patterns, analyse and evaluate them, but it also means creating new solutions on its own. Machine learning, on the other hand, is a subset of artificial intelligence, so to speak, and its feature is self-improvement based on the data and information provided. Machine learning involves the use of special algorithms through which the processes of data ingestion and analysis occur. This can be done in three ways (Wodecki, 2018):

- supervised learning – which means constant human control by providing the system with data along with the solution to the problem. After introducing enough sample information, the system will be able to independently assess the new incoming data and evaluate it in an appropriate manner.
- unsupervised learning – like supervised learning with the difference that during training the system receives data without solving the problem and its role is to appropriately classify information into a given number of categories.
- reinforcement learning – which is a special case of supervised learning with the difference that the system learns based on feedback from the environment rather than by having prepared feedback from the training set.



The topic of using machine learning in share price forecasting has been an area of research interest for some time. In a study on the potential of using machine learning for the Bitcoin cryptocurrency in a 2019 paper, the authors observed the potential for a 10% increase in price prediction performance compared to other methods (Fernandes & Mallqui, 2019). Similar conclusions regarding the benefits of using machine learning have also been recognised by researchers who have focused on only one company in a portfolio. In particular, their study focused on the usefulness of supervised machine learning algorithms (Torres et al., 2019). In the 2020 study, on the other hand, the researchers focused on analysing three companies from the binding sectors of finance, IT and health sciences listed on the National Stock Exchange. The study took a long time period into account, as the training data covered a period of six years. The results also suggest the possibility of obtaining attractive returns based on machine learning (Mondal et al., 2020).

In all the studies cited, machine learning is an effective tool for forecasting the price of market-listed financial instruments. Given the considerations so far, the authors have attempted to fill the research gap by carrying out the research set out in the purpose of this article.

Methodology adopted in the study

This paper uses the Azure Microsoft Machine Learning Studio tool to enable machine learning based calculations. It is a widely available cloud computing platform that provides an investor interested in creating a model and testing it. An important assumption of the research performed in the study is the adoption of a short investment horizon, and consequently, data from only five preceding trading sessions were intentionally used for the calculations. This approach's rationale was to consider only the most recent data.

1. The companies used in the calculation were those that were part of the WIG20 index in September 2021. These companies are: Asseco

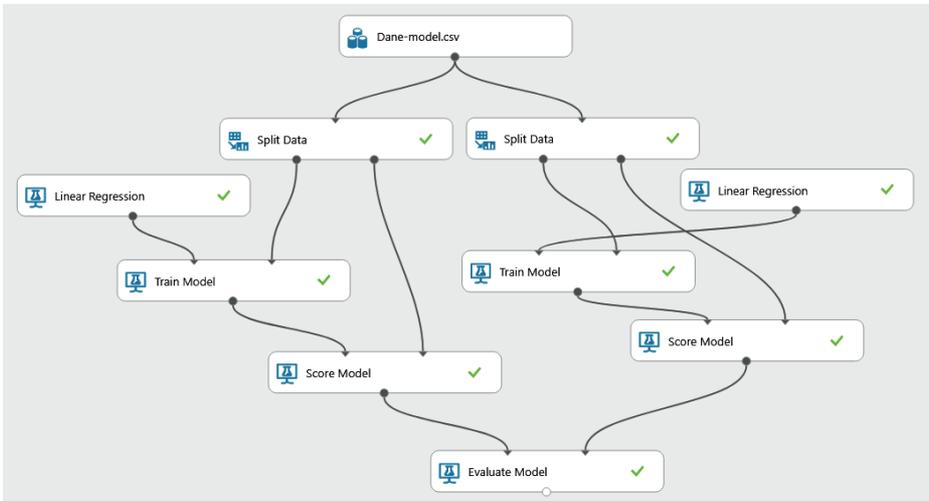
Poland SA (ACP), Allegro.eu SA (ALE), CCC SA (CCC), CD Projekt SA (CDR), Cyfrowy Polsat SA (CPS), Dino Polska SA (DNP), Jastrzębska Spółka Węglowa SA (JSW), KGHM Polska Miedź SA (KGH), LPP SA (LPP), Grupa Lotos SA (LTS), Mercator Medical SA (MRC), Orange Polska SA (OPL), Bank Polska Kasa Opieki SA (PEO), PGE Polska Grupa Energetyczna SA (PGE), Polskie Górnictwo Naftowe i Gazownictwo SA (PGN), Polski Koncern Naftowy ORLEN SA (PKN), Powszechna Kasa Oszczędności Bank Polski SA (PKO), Powszechny Zakład Ubezpieczeń SA (PZU), Santander Bank Polska SA (SPL) i Tauron Polska Energia SA (TPE).

2. The forecast includes the closing price for the trading session on 13.09.2021.
3. The calculations were based on the opening, closing, maximum and minimum prices for the five sessions preceding the one for which the closing price forecast was made, as well as on the opening price from that session.
4. Having historical data as mentioned in point 3 and the current session opening price, as well as having the closing price forecast for the current session based on the machine learning model, an investor is able to take a long position on the market after the opening at the opening price or at a price lower than the opening price, if the forecast assumes the closing price to be higher than the opening price and the price fluctuation allows it – for the sake of simplicity the opening price was used in calculating the strategy effectiveness.
5. If the forecast assumes closing at a level lower than the opening one, the trader does not take a position on the market.
6. After taking a long position, the investor closes it at the closing price by placing an appropriate order to close the session at the market price.
7. The calculations were made according to two schemes. The first assumes teaching the model using 50% of the companies selected randomly from all twenty, while the second uses 80% of the companies selected randomly from among all twenty.
8. The number of companies for which forecasts were made for the first scheme is ten, for the second four.

9. For simplicity, the commission for orders was omitted.
10. In conclusion, the rates of return for both schemes were calculated, and the level of forecasting error was calculated: mean absolute error, root mean square error, approximation error and the coefficient of determination R^2 was calculated.

Figure 1 shows an illustrative diagram of the machine learning model construction used in this study.

Figure 1. Illustrative diagram of the machine learning model construction used in the predictions



Source: Azure Microsoft Machine Learning Studio.

The individual modules shown in Figure 1 are:

- “Data-model.csv” – data covering historical quotations for WIG 20 companies in the analyzed period,
- “Split data” – a module that randomly selects from 20 companies those that will be used to “train” the model and those on which the model parameters will be applied,
- “Linear regression” – linear regression module,

- “Train model” – learning module based on test data selected by the “Split Data” module,
- “Score Model” – forecasting module,
- “Evaluate Model” – module calculating model fitting error and coefficient of determination.

Results obtained

Using calculations based on machine learning, the values of forecasted closing prices for the analyzed session were obtained for the teaching set comprising 50% and 80% of the total number of WIG 20 companies, which is presented in Tables 1 and 2. Additionally, error values for forecasts were determined and presented in Table 3.

Table 1. Forecasted and actual values for the learning set comprising 50% of the total number of WIG 20 companies

Company (1)	Opening (2)	Closing (3)	Forecasted closing (4)	Theoretical profitin PLN (5) = (3) – (2)	Theoretical transaction profitability (6) = (5) / (2)
CPS	33.96	34.34	34.32	0.38	1.12%
KGH	181	178.25	179.51	–	–
PZU	37.24	37.64	38.07	0.4	1.07%
JSW	52.02	54.22	53.06	2.2	4.23%
MRC	168.5	159	161.58	–	–
ACP	84.95	85.9	85.28	0.95	1.12%
CCC	119	118.6	119.56	–	–
TPE	3.53	3.65	3.61	0.12	3.40%
ALE	63.61	63.45	63.48	–	–
PKO	43.21	43.72	43.7	0.51	1.18%

Source: Calculations based on Azure Microsoft Machine Learning Studio and stock quotes of selected companies.

Table 2. Forecasted and actual values for the learning set comprising 80% of the total number of WIG 20 companies

Company (1)	Opening (2)	Closing (3)	Forecasted closing (4)	Theoretical profit in PLN (5) = (3) – (2)	Theoretical transaction profitability (6) = (5) / (2)
JSW	52.02	54.22	53.25	2.2	4.23%
PKO	43.21	43.72	43.22	–	–
TPE	3.53	3.65	3.59	0.12	3.40%
ALE	63.61	63.45	63.58	–	–

Source: Calculations based on Azure Microsoft Machine Learning Studio and stock quotes of selected companies.

Table 3. Forecast error values

Error name	Error value for learning setcovering 50% of companies	Error value for learning setcovering 80% of companies
Average absolute error	0.711202	0.331053
Root medium square error	1.053273	0.495408
Approximation error	0.15466	0.017604
Coefficient of determination R2	0.999622	0.999528

Source: Calculations based on Azure Microsoft Machine Learning Studio.

Analysing the results shown in Tables 1 and 2, we can come to the general conclusion that the use of forecasts allows an investor to take positions in the market and generate profit, provided that the conditions for taking a position are met, i.e. according to the forecast, the closing price will be higher than the opening price. In other words, the trader should not trade on that day when the forecast closing price is lower than the opening price.

Table 1, which shows the results of forecasts using a 50% learning set, presents positive returns for every deal made. Whenever the system indicates a potential loss on the transaction, investors should not make the deal. In fact, the results obtained in reality confirm that with both potential gains and potential losses the system based on machine learning indicated correctly. The exception was the result obtained in relation to one company, that is, CCC, but in

this case the difference resulting from the system and the actual result were tiny, which could be offset by the cost of commissions. Table 2, which shows the results of forecasts using the 80% learning set, also shows positive returns for each deal. Table 3 shows the values of selected forecast and model fitting errors. As it can be observed, using more companies to teach the model makes the error values lower, with the increase in the number of companies introduced to the teaching set the coefficient of R2 determination indicates a better model fit. In Table 2, which shows the results of forecasts using the 80% teachinggroup of companies, positive returns were also obtained for each transaction. Table 3 shows the values of selected forecast and model fitting errors. As we can see, using a larger number of companies to teach the model, error values are lower and the coefficient of determination R2 indicates a better model fit.

Conclusions

The purpose of this study was to investigate and evaluate the applicability of machine learning to investment decision-making in stock markets. The results of the presented calculations indicate that an investor using machine learning based closing price forecasts could earn positive returns. Depending whether we use 50% or 80% teachingset of the companies, daily returns can range from 1.07% to even 4.23%.This applies only if the closing forecast indicates the value of this closing at a level higher than the opening price. Referring to the hypothesis formulated at the beginning of the article, if the use of machine learning can contribute to obtaining a positive rate of return by a stock market player making short-term investments, it can be stated that it has been verified positively.

The results obtained will undoubtedly be a reference point for further research conducted by the authors, including the use of instruments that allow to generate profits during price drops (futures contracts), a different interval of data (daily, weekly, monthly), or the use of more companies to improve the quality of forecasts.



The scientific contribution presented in this research consists mainly of the application of machine learning to short-term trading, which can be used by investors as an effective tool for making capital allocation decisions. In particular, this method can be helpful for investors trading for very short periods (daytrading).

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