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**MULTI-CRITERIA DECISION-MAKING METHODS (MCDM): A BIBLIOMETRIC ANALYSIS (1974-2024)**

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**Neylan Kaya**

Akdeniz University, Business and Administration, Antalya, Turkiye.

[neylankaya@akdeniz.edu.tr](mailto:neylankaya@akdeniz.edu.tr), ORCID: 0000-0003-2645-3246

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**ABSTRACT**

**Purpose-** Multi-criteria decision-making (MCDM) is considered a complex decision-making (DM) tool that integrates both quantitative and qualitative factors. In recent years, various MCDM techniques and approaches have been proposed to select the best possible alternative. The overall aim of this study was to identify the tendencies and trends of the discipline over the past 50 years by conducting a bibliometric analysis of 10,387 studies published between 1974 and 2024 in the realm of multi-criteria decision-making methods (MCDM).

**Methodology-** In this regard, the Web of Science Core Collection database was utilized to retrieve articles related to "Multiple criteria decision-making", from which bibliometric data were extracted and analyzed. These studies were analyzed within the context of the number of publications by year, types of publications, language of publications, citation analysis, cooperation among countries, common citation networks and concept-topic orientations

**Findings-** The analysis unveiled a rapid increase in the number of publications after 2012, with studies predominantly taking the form of articles and being published in English. Besides, engineering emerged as the field with the highest number of publications, with the Analytical Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) being the most frequently used concepts. Zavadskas was identified as the author with the most publications and most cited on the subject. The journal with the highest number of citations was European Journal of Operational Research. Furthermore, the USA and China play a pivotal role in cooperation between countries.

**Conclusion-** This study is expected to make a valuable contribution to the relevant field as a determinant of some of the most effective researches, including influential journals, articles and authors in MCDM. Moreover, it may serve as a guide for researchers in terms of documenting the common tendencies in the field of MCDM

**Keywords:** Decision, decision making, multi-criteria decision making, bibliometric analysis, network analysis**JEL Codes:** C00, C02, C60**1. INTRODUCTION**

Individuals often make decisions –whether consciously or unconsciously- that can be classified as right or wrong in daily life. Decision-making is the process by which individuals, managers, institutions or decision-makers select one option from several alternatives (Işığışık, 2015). Real-world decision-making problems are typically complicated, and structures that focus solely on analyzing a single criterion or perspective may prove inadequate (Zavadskas & Turskis, 2011). The variety of criteria considered during decision-making and the complexity of the problems in real life make the process of decision-making challenging, leading to the emergence of multi-criteria decision-making. MCDM involves selecting the most suitable alternative from a set of options based on multiple criteria (Gürsaka, 2015). Ren, Xu and Gou (2016) noted that multi-criteria decision making method (MCDM) is the process of identifying the most appropriate alternative that behaves best in a limited set of alternatives with multiple criteria. The problem in MCDM lies in choosing a subset of alternatives that best aligns with both internal and external (Brans & Mareschal, 1992). Prioritizing criteria plays a crucial role in MCDM, as it helps in identifying the most suitable option (Yager, 2004). In his study, Yager (2004) prioritized and patterned MCDM problems through using the Bellman and Zadeh paradigm along with The Ordered Weighted Averaging (OWA) operator.

The number of publications on MCDM techniques has increased after 2000. Nevertheless, there has been a proliferation of diverse MCDM methods, the tendency to combine different MCDM techniques and the integration of them with the uncertainties encountered in daily problems (Marttunen, Lienart & Belton, 2017).

Judicial statements are usually subjective and ambiguous. Zadeh (1965) introduced the fuzzy set theory to address these challenges, aiming to quantify the ambiguity and subjectivity inherent in human judgments and to articulate linguistic terms

within the decision-making process. Belman and Zadeh (1970) were among the pioneering researchers to apply the fuzzy theory to decision-making problems. This approach offers decision-makers a systematic, consistent and efficient way to solve complex decision problems (Chen & Klein, 1997). The greatest strength of MCDM lies in its capacity to solve intricate problems. Today, widely used classical models are inadequate (Zavadskas & Turskis, 2011). Contemporary MCDM techniques focus on not only choosing among options but also discovering options, enhancing the learning process and fostering the discovery of common solutions (Belton & Stewart, 2002).

Today, MCDM is paramount in medical diagnosis, obtaining information, financial decision-making, pattern recognition and its use in new technologies (Yager, 2018; Predrycz, Ekel & Parreiras, 2010). In the future, MCDM methods will turn towards the areas of analysis of different scaling methods, analysis of preference relations, analysis of aggregation procedures, the study of grey relations, the study of fuzzy relations, the development and modification of new mathematical models to solve outranking problems (Zavadskas & Turskis, 2011). Recently, MCDM has been used to solve field problems such as energy (Dong, Li & Huang, 2018; Lee & Chang, 2018), environment and sustainability (An et. al., 2018; Cereska et. al., 2016), supply chain management (Yazdani, Zolfani & Zavadskas, 2016; Yu & Hou, 2016), material (Kiani, Liang & Gross, 2018; Giorgetta et. al., 2017), quality management (Sofiyabadi, Kolahi & Valmohammadi, 2016; Lupo, 2016), construction and project management (Wanga et. al., 2017; Jalilibala, Bozorgi-Amirib & Khosravi., 2018), security and risk management (Ishola, 2017; Gao, Liang & Xuan, 2016), production systems (Ranjan et al., 2016; Prakash & Barua, 2016) technology and information management (Lee et al., 2017; Chen et al., 2018), strategic management (Duan et al., 2017; Singh et. al., 2016), production management (Ranjan, Chatterjee & Chakraborty 2016; Prakash & Barua, 2016) and tourism management (Bagheri, Shojaei & Khorami 2018; Xiong et. al., 2017).

Bibliometrics is a quantitative method which employs statistical analysis to examine bibliographical information (Skinner, 2015; Borgman & Furner, 2002; Moed, 2005; Diodata, 2012). This approach provides an overall picture of a research field, categorizing it based on articles, authors and journals (Merigó & Yang, 2017). The earliest bibliometric study, known as "Zipf Law", was conducted by Zipf in 1934, focusing on words within quantitative practice researches (Jackson, 2012; Cowton, 1998). In 1936, Bradford conducted a mapping by using the subject sections of bibliographies to investigate the history of the subject named "Bradford Law" (Jackson, 2012; De Bellis, 2009). Another study in 2001 by Losee involved analyzing the frequency of literary reviews through a bibliography, calculating word counts for 400 selected documents that employed both Bradford Law and Zipf Law (Jackson, 2012; Bakulina, 2008).

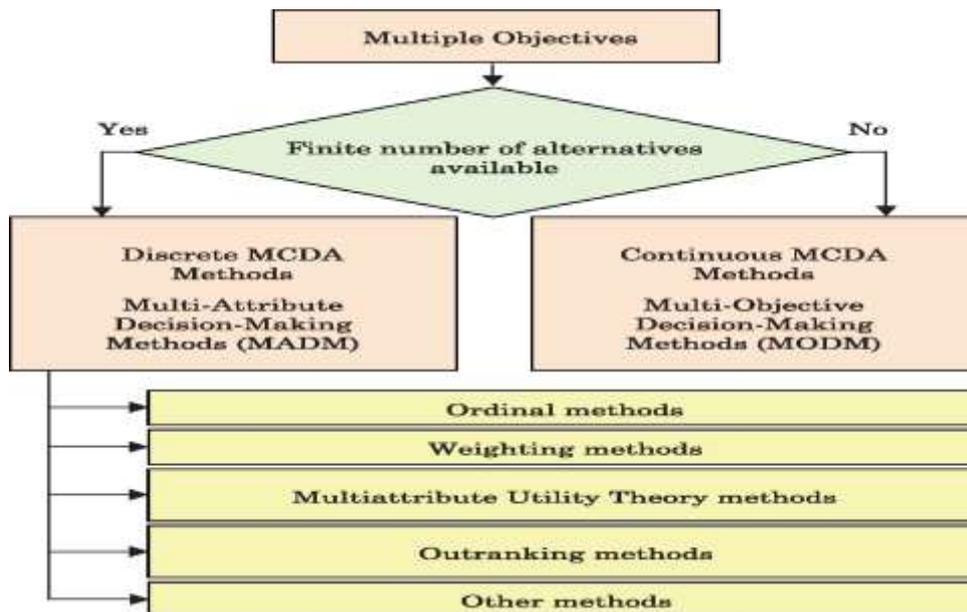
Traditional bibliometric analysis is based on ranking elements that analyze characteristics such as author characteristics, research methodology, and citations. Two commonly employed approaches are citation analysis and keyword analysis. Citation analysis indicates the primary contributors to a field, while keyword analysis highlights the predominant conceptual areas in a research domain (Diodato, 2012). Bibliometric research hold significant importance as they serve to gauge the current state of the subject under investigation, assess existing knowledge and comprehension, evaluate research quality, and inform future studies in the field. Thus, this study analyzed bibliometric studies conducted in the field of MCDM, as indexed in WOS.

## **2. CLASSIFICATION OF MCDM METHODS**

As methods used to support decision-makers in problem solving evolve dynamically, precise classification poses challenges (Zavadskas & Turskis, 2011). Thus, different classification criteria are used by various researchers. One commonly cited classification divides MCDM methods into three groups (Francik et al., 2017); Methods of Multi-Attribute Utility Theory (MAUT), Methods of outranking and Interactive methods or multi-objective mathematical programming models. Francik et al. (2017) propose an alternative classification of MCDM (Figure 1).

Trzaskalik (2014a) and Trzaskalik (2014b) divided the discrete multi-criteria decision-making methods into 7 groups such as additive methods, the AHP method and related methods, verbal methods, Electre methods, Promethee methods, use of reference points, and interactive methods (Francik et. al. 2017; Trzaskalik, 2014a; Trzaskalik, 2014b).

Figure 1: Classification of Multicriteria Decision-Making Methods



Source: Kodikara, 2008; Piwowski, 2009; Kodikara, Sobczyk et. al., 2011; Francik et. al., 2017

### 3. BIBLIOMETRIC STUDIES IN THE FIELD OF MCDM

Recently, numerous studies have been specifically published on giving information regarding the development of MCDM methods and their applications across various domains (Mardani, Jusoh, & Zavadskas, 2015). This study attempts to present a bibliometric analysis using WOS database to elucidate the incrementally growing interest in MCDM techniques and approaches. In this section, the relevant literature on MCDM is displayed.

Chen et al. (2019), analyzed 1485 publications on the Analytic Network Process (ANP) indexed in WOS between 1996-2018. The research results revealed that 'Expert Systems with Applications' emerged as the most frequently cited journal with 118 articles. Besides, Sarkis's work (2003) titled "A strategic decision framework in green supply chain management" was identified as the most referenced publication. The keyword analysis depicted that ANP prominently appeared in keywords predominantly between 2011 and 2016, followed by MCDM, the Decision-making Trial and Evaluation Laboratory (DEMATEL), Fuzzy ANP, AHP, supplier selection, balanced scorecard, quality function spread, Geographic Information System (GIS), and combinations of ANP with various MCDM techniques. Taiwan led in the number of publications on ANP, with 436 articles, and Tzeng emerged as the researcher with the highest number of publications on ANP, totaling 56 articles.

Yu, Xu and Wang (2018) conducted a bibliometric analysis on the fuzzy theory research carried out in China over the past three decades. The study analyzed 12,936 studies on fuzzy theory conducted by Chinese researchers during this period, examining the geographic distribution of the studies, international cooperation, subject categories, journals of publication, and their contribution to the publications. Most studies were conducted in the Beijing region with American cooperation. Zadeh's (1965) study was prominent in terms of keywords such as total operator, system, algorithm, uncertainty, numerical examples, model, optimization, and linear matrix inequality. Engineering emerged as the dominant subject category. Most studies in this area were published in the journal "Fuzzy Sets and Systems".

Zyoud and Fuchs-Hanusch (2017) conducted a bibliometric analysis of 10,188 studies on AHP and 2412 studies on TOPSIS. The aim was to identify trends and conditions in research on these methods. The majority of studies on the AHP and TOPSIS were conducted in the field of engineering in China in 2016. The journal "Expert Systems with Application" emerged as the primary publication venue for studies on AHP and TOPSIS methods. The first study on AHP was published by Saaty (1977), while the first study on TOPSIS was authored by McCahon, Hwang and Tillman (1983) and appeared in Scopus. The University of Tehran hosted the most studies on AHP, while Islamic Azad University led in studies on TOPSIS.

Adunlin, Diaby and Xiao (2014) conducted a systematic bibliometric analysis on the use of MCDM in healthcare services. The research on the subject was carried out through scanning electronic databases, conference attendances and journals. The scope of the study consisted of 205 publications published in English between 1980 and 2013. An uptick in studies on the subject was noted in the years 1990, 1997, 1999, 2005, 2008 and 2012. Most studies regarding the subject were published on diagnosis and treatment in the journal of "Medical Decision Making" in the USA in 2012.

#### 4. DATA AND METHODOLOGY

The study aims to identify the bibliometric characteristics of the studies in the domain of MCDM retrieved from the WOS database. The dataset consisted of 12,908 studies published in the field of MCDM between 1974 and 2024, as indexed in WOS. The search query employed the title "Multicriteria decision-making" within the WOS platform, yielding bibliometric data pertinent to the research objectives.

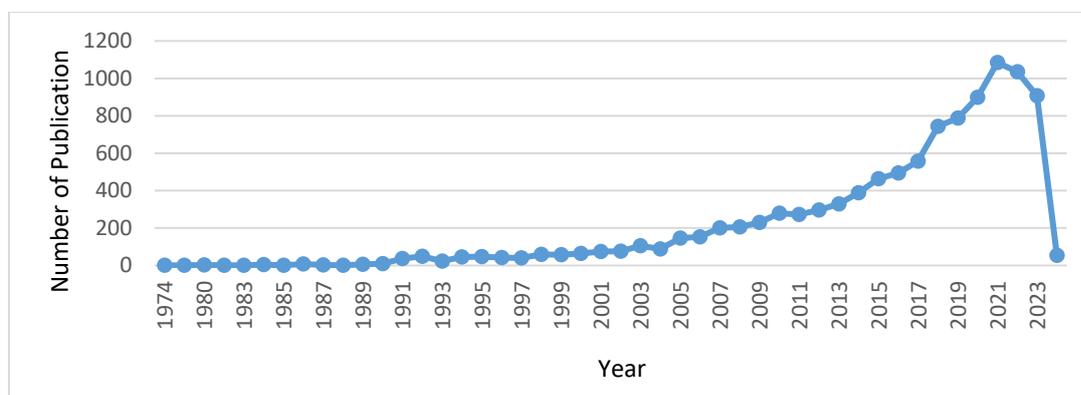
The studies published in the field of MCDM were analyzed based on various parameters, including the years of publication, research areas, types of studies, author names, language employed, authors' countries of origin, international cooperation, citations received from sources indexed in WOS, cited authors and keywords. The Vosviewer software was deployed to identify the collaborations among countries in the field of MCDM, common citation networks and concept-subject trends within the field.

#### 5. FINDINGS AND DISCUSSIONS

##### 5.1. Number of Publications by Year

The bibliometric analysis results suggested a notable trend towards the field starting in 2000. Figure 2 depicts the numbers of publications by year in the field of MCDM. The Pearson correlation coefficient between the years and the number of publications was found to be 0.78 ( $p < 0.05$ ), indicating a statistically significant relationship with a high correlation between the years and the number of publications.

**Figure 2: Number of publications in the field of MCDM between 1974-2024**



The distribution of 10,387 studies published in the field of MCDM between 1974 and 2024 by year reveals the greatest number of studies occurred in 2021 ( $n=1085$ ). It's worth noting that the decrease in the number of publications in 2024 may be attributed to the fact that the year has not yet concluded. The studies conducted within the last decade constituted 53.05 % of the total number of publications. This shows a notable rise in the number of studies, particularly in the last decade (Table 1).

**Table 1: Distribution of Publications by Years**

Year	Number of papers	Percentage (%)
1974-1984	15	0,14
1985-1995	233	2,24
1996-2006	911	8,77
2007-2017	3717	35,78
2018-2024	5511	53,05

##### 5.2. Publication Types

Table 2 displays the distribution of publication types in the field of MCDM.

**Table 2: Distribution of Publication by Types**

Publication type	Number of papers	Percentage (%)
Article	8643	78,50
Proceeding Paper	1541	13,99
Review Article	404	3,66

Book Chapters	185	1,68
Others	237	2,15

The studies in the field were categorized into 16 types, with some publications falling under multiple types. Some studies were written in different document types. Upon analyzing 11010 studies, they were found to be mostly articles and proceedings, and they numbered 10184 in total (92.49%).

### 5.3. Publication Languages

The analysis findings showed that studies were written in 18 different languages. The overwhelming majority, comprising 10,176 publications (97.95%) out of 10,387, were written in English. This was followed by 55 publications in Spanish, 43 in Portuguese, 25 in Turkish and 20 in Russian. Table 3 displays the distribution of the publications by language.

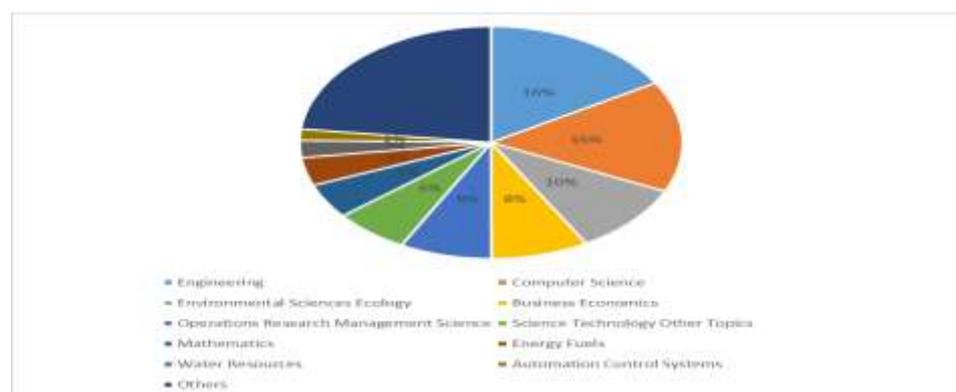
**Table 3: Distribution by Publication Language**

Language	Number of papers	Percentage (%)
English	10176	97,95
Spanish	55	0,52
Portuguese	43	0,41
Turkish	25	0,24
Russian	20	0,19
Others	68	0,66

### 5.4. Publication Trends by Research Area

Figure 3 illustrates the areas predominantly researched in studies on MCDM.

**Figure 3: The 10 Mostly Studied Research Areas Regarding MCDM between 1974-2024**



The top 10 researched areas regarding MCDM were respectively engineering, computer science, environmental sciences ecology, business economics, operations research management science, science technology other topics, mathematics, energy fuels, water resources and automation control systems. Some studies took place in different application field. The contribution of the research areas to MCDM are presented in Table 4.

**Table 4: Contribution of the Research Areas**

Application field	Number of papers	Percentage (%)
Engineering	2974	16,42
Computer Science	2805	15,49
Environmental Sciences Ecology	1781	9,83
Business Economics	1490	8,22
Operations Research Management Science	1408	7,77
Science Technology Other Topics	1152	6,36
Mathematics	880	4,86
Energy Fuels	710	3,92
Water Resources	433	2,39
Automation Control Systems	282	1,55
Others	4191	23,14

Engineering, the most researched area, constituted 16.42% of the studies conducted in the last 50 years.

**5.4. Top Ten Lists of Corresponding Authors, their Countries of Residence and the Journal**

The bibliographic analysis showed that Zavadskas conducted the greatest number of studies as a corresponding author. The total number of publications between 1974 and 2024 by the top ten corresponding authors, who had the highest number of publications on MCDM, accounted for 0.05% of the total number of publications on the subject. Authors with the highest number of publications related to the field as corresponding authors are depicted in Figure 4.

**Figure 4: Top 10 Authors Studying Mostly in the Field of MCDM between 1974 and 2024**

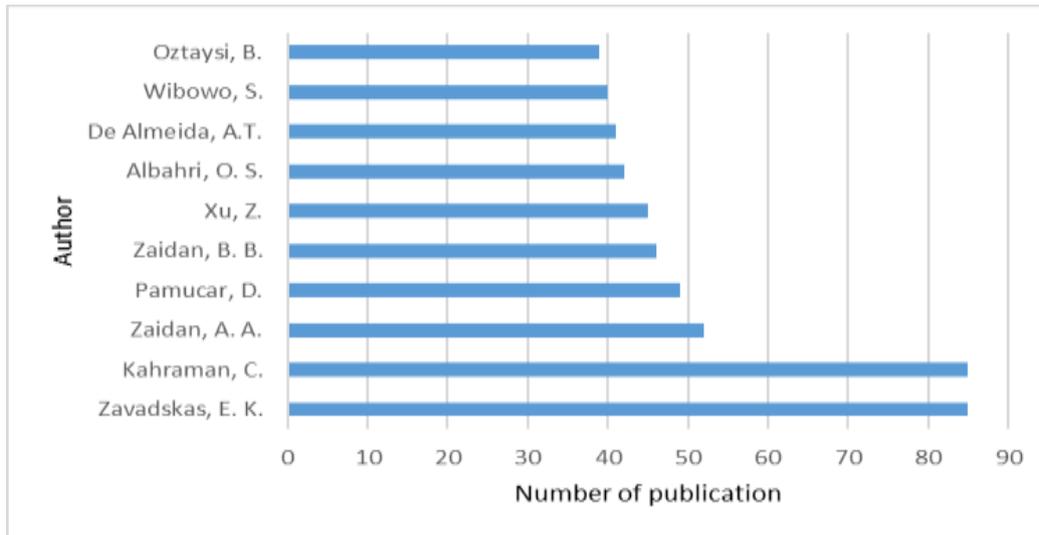


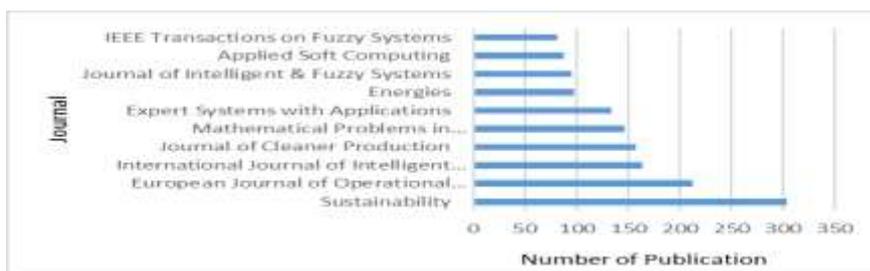
Table 5 summarizes the top 10 authors who have extensively contributed to the field as corresponding authors, along with their countries, number of publications, percentages, total number of publications citing these authors, and average citation numbers.

**Table 5: Top 10 Authors by Number of Publications**

Authors	Number of papers	Total number of citing publications
Zavadskas, E. K.	85	6985
Kahraman, C.	85	4667
Zaidan, A. A.	52	2147
Pamucar, D.	49	1807
Zaidan, B. B.	46	2123
Xu, Z.	45	3950
Albahri, O. S.	42	1595
De Almeida, A.T.	41	910
Wibowo, S.	40	255
Oztaysi, B.	39	1715

Upon analyzing the total number of publications citing the works of the top 10 authors, Zavadskas emerged as the leader in terms of total citations. Figure 5 depicts the journals publishing the highest number of studies on MCDM.

**Figure 5: Top 10 Journals Publishing the Highest Number of Studies on MCDM between 1974-2024**



With 304 studies in the years analyzed, “Sustainability” was determined to be the journal publishing the greatest number of studies. The journals publishing the greatest number of studies on MCDM accounted for 0.14% of the total number of studies.

Table 6 displays the number of publications in the top 10 journals with the highest number of publications on MCDM, their percentages, the years when the greatest number of publications on MCDM were published in these journals, and the number of publications for that year, the years when these journals received the most citation on MCDM, and the number of citations for those year.

**Table 6: Top 10 Journals by the Number of Publications**

Journals	Number of papers	Number of citation
Sustainability	304	4366
European Journal of Operational Research	213	17142
International Journal of Intelligent Systems	164	8476
Journal of Cleaner Production	158	6272
Mathematical Problems in Engineering	147	1434
Expert Systems with Applications	134	10906
Energies	98	1501
Journal of Intelligent & Fuzzy Systems	95	2313
Applied Soft Computing	88	4008
IEEE Transactions on Fuzzy Systems	82	8803

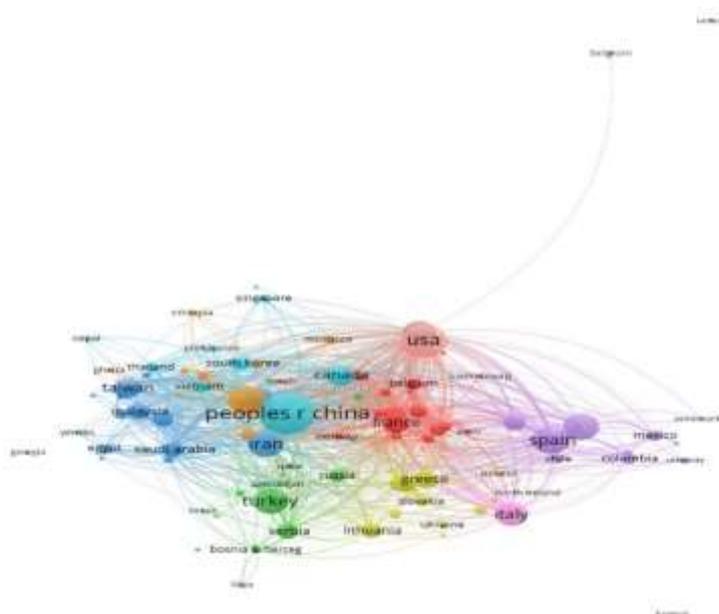
European Journal of Operational Research and Expert Systems with Applications were the most cited journals on MCDM.

**5.5. Cooperation across Countries in MCDM Studies**

Researchers from various countries were found to cooperate on studies related to MCDM. The countries where researchers engaged in cooperative research on MCDM are presented in Figure 6.

The countries were counted once in studies including more than one author from the same country. The knots in the nets represent countries, and the connections between them signify the relations between the countries. Thicker connections between countries indicate stronger collaborative ties.

**Figure 6: Cooperation among Countries**

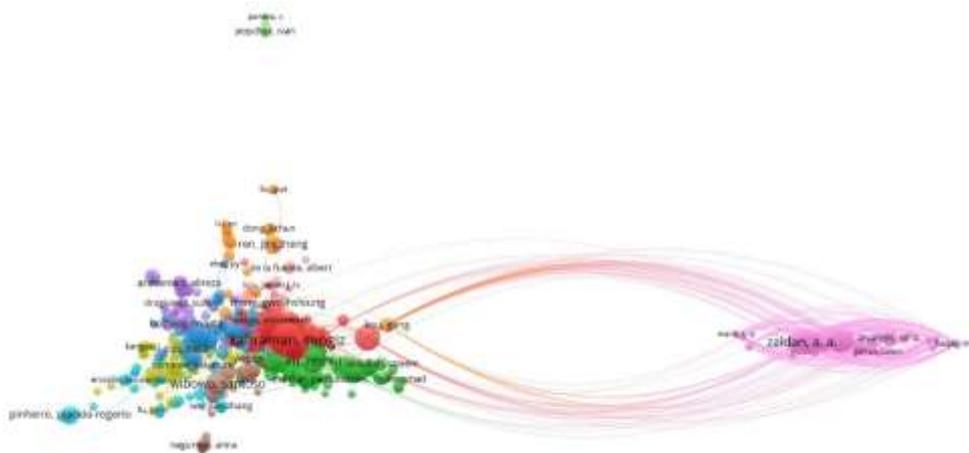




International Journal of Intelligent Systems	164	8476	1181
Journal of Cleaner Production	158	6272	733
Renewable&Sustainable Energy Reviews	71	6195	981
Fuzzy Sets and Systems	79	5616	481
Journal of Environmental Management	79	4515	452
Omega-International Journal of Management Science	70	4370	614
Sustainability	304	4366	955

The journals were ranked in the following order based on the number of citations received by their publications: European Journal of Operational Research, Expert Systems with Applications, IEEE Transactions on Fuzzy Systems. When considering the journals' total link strength to the other journals, their ranking was as follows: European Journal of Operational Research, Expert Systems with Applications and International Journal of Intelligent Systems. These journals were identified together based on network density. Figure 8 presents the authors who were cited together in these journals.

**Figure 8: Author Joint Citation Network Map**



The size of the text font and the size of the circles denote authors who were cited more. Nine sets of authors were mainly formed, each exhibiting strong link among the authors within the set.

**Table 9: Top 10 Authors Contributing to the Subject**

Author	Number of Citation	Total Link Strength
Zavadskas, E. K.	6985	1746
Yager, R. R.	5776	407
Yager, R. R.	4951	918
Kahraman, C.	4667	1708
Xu, Z.	3950	764
Turskis, Z.	3720	957
Ye, J.	3037	326
Garg, H.	2951	504
Tzeng, G-H	2548	443
Herrera, F.	2324	127

In the 10387 studies published on MCDM, the most cited authors were determined to rank as Zavadskas (n=6985), Yager (n=10727), Kahraman (n= 4667), Xu (n=3950), Turskis (n=3720) and Ye (n=3037). These authors were cited together with the others (Table 9).

### 5.7. Popular MCDM Research Topics and Trends

A network analysis revealed frequent co-occurrences of keywords within the related literature. A total of 23,587 keywords were identified across 12,908 studies. Figure 9 shows the network analysis of the keywords in the publications on MCDM.

Figure 9: Keyword Network Map

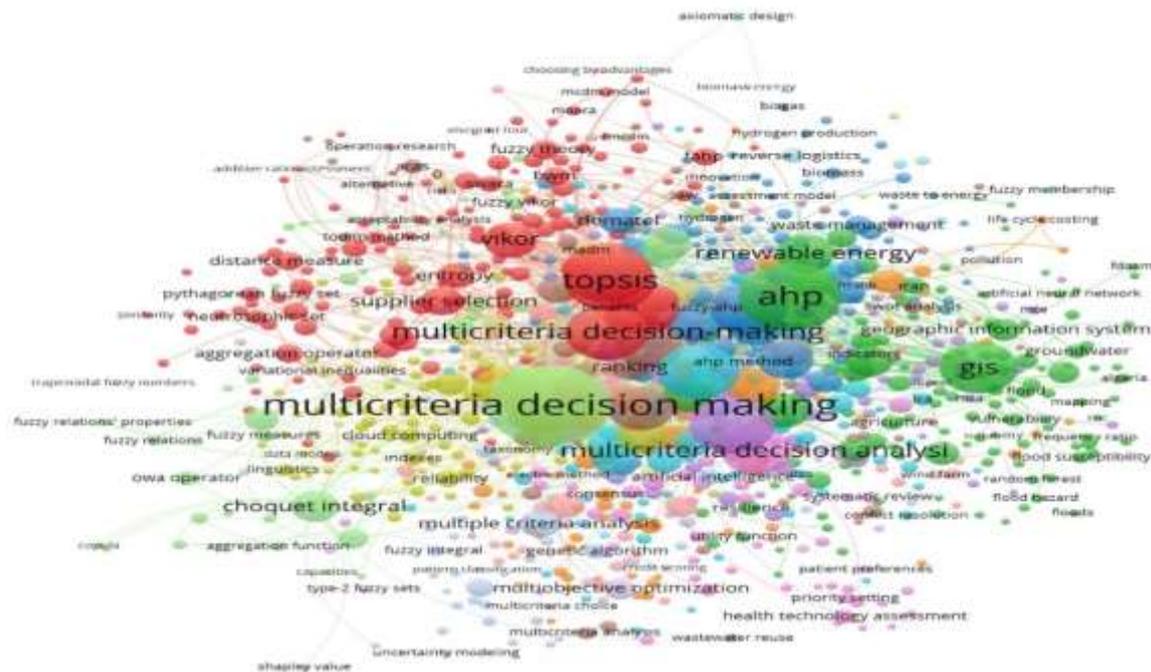


Table 10 shows the most popular methods, concepts and frequency of their use on MCDM.

Table 10: Popular Methods and Concepts

Method/Concept	Frequency	Total Link Strength
Ahp	1094	2523
Topsis	405	1075
Geographic Information System (GIS)	296	685
Sustainability	285	683
Uncertainty	171	511
Renewable Energy	166	434
Fuzzy Sets	161	490
Sustainable Development	152	415
Fuzzy Logic	152	358
Promethee	143	368

The most frequently used keyword was noted to be AHP (n=1094). This was followed by TOPSIS (n=405). AHP, TOPSIS, Geographic Information System (GIS), sustainability, uncertainty, renewable energy, fuzzy sets, sustainable development, fuzzy logic, Promethee were the prominent topics in the studies on MCDM.

AHP, the most frequently used term in MCDM, is often associated with methods such as the TOPSIS, Fuzzy AHP, Fuzzy TOPSIS, VIKOR, PROMETHEE and Dematel. Besides, it is commonly linked with concepts including supplier selection, sustainability, fuzzy logic, Geographic Information System (GIS), and site selection.

## 6. CONCLUSION AND IMPLICATIONS

In recent years, MCDM methods have been developing rapidly with various modelling techniques and approaches. This surge in development has coincided with a dramatic increase in publications within the field. Easy access to the developing information, coupled with challenges in interpretation, along with the proliferation of software tailored for MCDM, has fueled a rise in studies within this domain. This study aims to conduct a comprehensive bibliometric analysis of 10,387 studies published between 1974 and 2024 in the field of MCDM, shedding light on key trends and insights within the discipline. The

study is of great importance as it reveals the systematics of the field by reporting the trends and tendencies in the last 50 years by themes. The study includes the relevant articles available on the WOS database. This study employed text mining and visualization analysis to comprehensively analyze a substantial volume of data and categorize it for interpretation. A total of 10387 studies conducted between 1974 and 2024 were analyzed. The results showed that the interest in MCDM increased after 2000, with the greatest number of studies recorded in 2021 (n=1085). MCDM studies were mostly written in the form of articles, and in English. The studies searched in WOS spanned across 112 different fields. Most of these studies were in the fields of engineering (n=2974), computer science (n=2805), and environmental sciences ecology (n=1781). Complex decision-making problems in the field of engineering increased the application of MCDM methods in the field.

Another finding of the study suggested the prominent role of the USA in fostering cooperation among countries. Turkey took the 3rd place in both the number of publications and citations. Among journals, European Journal of Operational Research was determined as the most cited within citation network analysis. Zavadskas emerged as the most cited author. The study titled "Generalized Orthopair Fuzzy Sets" written by Yager in 2017 was identified as the most up-to-date study among the top 10 most cited sources.

It may be wise to mention that applied studies held a considerable position within the field. The results of the keyword network analysis revealed that MCDM was frequently associated with various methods, including Ahp, Topsis, Vikor, Fuzzy Topsis, Fuzzy Ahp, Promethee, Dematel, as well as concepts involving decision making, supplier selection, sustainability, renewable energy and GIS. This study is expected to make a valuable contribution to the relevant field as a determinant of some of the most effective researches, including influential journals, articles and authors in MCDM. Moreover, it may serve as a guide for researchers in terms of documenting the common tendencies in the field of MCDM.

## REFERENCES

- Adunlin, G., Diaby, V., Xiao, H. (2014)..Application of multicriteria decision analysis in health care:a systematic review and bibliometric analysis. *Health Expectations*, 18(6), 1894-1995
- Bagheri, M., Shojaei, P., Khorami, M.T. (2018). A comparative survey of the condition of tourism infrastructure in Iranian provinces using VIKOR and TOPSIS, *Decision Science Letters*, 7(1), 87–102. <http://dx.doi.org/10.5267/j.dsl.2017.4.001>
- Bakulina, M. P. (2008). Application of the Zipf law to text compression, *Journal of Applied and Industrial Mathematics*, 2(4), 477-483.
- Bellman, R. E., Zadeh, L. A. (1970). Decision-making in a fuzzy environment, *Management Science*, 17(4), 141-164. <https://doi.org/10.1287/mnsc.17.4.B141>
- Belton, V., Stewart, T. J. (2002). *Multiple criteria decision analysis - An integrated approach*, Boston, Kluwer.
- Borgman, C. L., Furner, J. (2002). Scholarly communication and bibliometrics. *Annual Review of Information and Technology*, 36(1), 2-72. <https://asistdl.onlinelibrary.wiley.com/doi/epdf/10.1002/aris.1440360102>
- Chen, C. B., Klein, C. M. (1997). An efficient approach to solving fuzzy MADM problems, *Fuzzy Sets and Systems*, 88(1), 51-67. [https://doi.org/10.1016/S0165-0114\(96\)00048-6](https://doi.org/10.1016/S0165-0114(96)00048-6)
- Chen, C. T., Huang, S. F., Hung, W. Z. (2018). Linguistic VIKOR method for project evaluation of ambient intelligence product, *Journal of Ambient Intelligence and Humanized Computing*, 1-11. <https://doi.org/10.1007/s12652-018-0889-x>
- Chen, Y., Jin, Q., Fang, H., Lei, H., Hu, J., Wu, Y., Chen, J., Wang, C., Wan, Y. (2019). Analytic network process: Academic insights and perspectives analysis, *Journal of Cleaner Production*, 235, 1276-1294.
- Cowton, Christopher J. (1998). The use of secondary data in business ethics research, *Journal of Business Ethics*, 17 (4), 423-434. <https://doi.org/10.1023/A:1005730825103>
- De Bellis, N. (2009). *Bibliometrics and citation analysis*, Lanham, Scarecrow Press Inc.
- Diodato, V. (2012). *Dictionary of bibliometrics*, Routledge, Taylor & Francis Group, Newyork, The Haworth Press.
- Dong, J., Li, R., Huang, H. (2018). Performance Evaluation of Residential Demand Response Based on a Modified Fuzzy VIKOR and Scalable Computing Method, *Energies*, 11(5), 1097. <https://doi.org/10.3390/en11051097>
- Duan, R., Hu, L., Lin, Y. (2017). Fault diagnosis For complex systems based on dynamic evidential network and multi-attribute decision making with interval numbers, *Eksplatacja i Niezawodnosc – Maintenance and Reliability*, 19 (4), 580–589. <http://dx.doi.org/10.17531/>
- Francik, S., Pedryc, N., Knapczyk, A., Wojcik, A., Francik, R., Lapczynska-Kordon, B. (2017). Bibliometric analysis of multiple criteria decision making in agriculture, *Technical Sciences*, 20(1),17-30. <http://dx.doi.org/10.31648/ts.2906>
- Gao, Z., Liang, R., Xuan, T. (2016). VIKOR Method for Ranking Concrete Bridge Repair Projects with Target-Based Criteria, *Results in Engineering*, 3, 1-9. <https://doi.org/10.1016/j.rineng.2019.100018>
- Giorgetta, A., Cavallinib, C., Arcidiacono, G., Citti, P. (2017). A Mixed C-VIKOR Fuzzy Approach for Material Selection during Design Phase: A Case Study in Valve Seats for High Performance Engine, *International Journal of Applied Engineering Research*, 12(12), 3117-3129.

- Gürsakar, S. (2015). Karar Verme, Çok Kriterli Karar Verme Yöntemleri, 1. Baskı, (Ed: M. Aytaç ve N. Gürsakar), Dora Yayıncılık, 243-272, Bursa.
- Ishola, A. (2017). Advances safety methodology for risk management of petroleum refinery operations, Doctoral Thesis, Liverpool John Moores University, Doctor of Philosophy, UK.
- Işığışık, E. (2015). Karar Verme, Mustafa Aytaç (Ed) ve Necmi Gürsakar (Ed), Dora Yayıncılık, 1-32, Bursa.
- Jackson, M. (2012). A Bibliometric analysis of green building literature, Doctoral Dissertation, Faculty of the School of Business and Technology Management, Northcentral University, Prescott Valley, Arizona.
- Jalilibala, Z., Bozorgi-Amirib, A., Khosravi, R. (2018). A hybrid lexicographic and VIKOR approach for prioritizing construction projects by considering sustainable development criteria, Journal of Project Management, 3, 131–142. <http://dx.doi.org/10.5267/j.ipm.2018.3.001>
- Kiani, B., Liang, R. Y., Gross, J. (2018). Material selection for repair of structural concrete using VIKOR method, Case Studies in Construction Materials, 8, 489–497. <https://doi.org/10.1016/j.cscm.2018.03.008>
- Kodikara, P. N. (2008). Multi-Objective Optimal Operation of Urban Water Supply Systems, PhD Thesis, Victoria University, Australia.
- Lee, H. C., Chang, C. T. (2018). Comparative analysis of MCDM methods for ranking renewable energy sources in Taiwan, Renewable and Sustainable Energy Reviews, 92, 883-896. <https://doi.org/10.1016/j.rser.2018.05.007>
- Lee, A. H. I., Kang, H. Y., Liou, Y. J. (2017). A Hybrid Multiple-Criteria Decision-Making Approach for Photovoltaic Solar Plant Location Selection, Sustainability, 9(2), 1-21. <https://doi.org/10.3390/su9020184>
- Lupo, T. (2016). A Fuzzy Framework to evaluate service quality in the healthcare industry: An empirical case of public hospital service evaluation in Sicily, Applied Soft Computing, 40, 468-478. <https://doi.org/10.1016/j.asoc.2015.12.010>
- Mardani, A., Jusoh, A., Zavadskas, E. K. (2015). Fuzzy multiple criteria decision-making techniques and applications - Two decades review from 1994 to 2014, Expert Systems with Applications, 42, 4126-4148. <https://doi.org/10.1016/j.eswa.2015.01.003>
- Marttunen, M., Lienart, J., Belton, V. (2017). Structuring problems for Multi-Criteria Decision Analysis in Practice: A Literature Review of Method Combinations, European Journal of Operational Research, 263(1), 1-17. <https://doi.org/10.1016/j.ejor.2017.04.041>
- McCahon, C. S., Hwang, C. L., & Tillman, F. A. (1983). A multiple attribute evaluation of Bayesian availability estimators. IEEE transactions on reliability, 32(5), 496-503.
- Merigo, J. M., Yang, J. B. (2017). A bibliometric analysis of operations research and management science, Omega, 27(1), 71-100. <https://doi.org/10.1016/j.omega.2016.12.004>
- Moed, H. F. (2005). Citation Analysis in Research Evaluation, Dordrecht, Netherlands: Springer.
- Piwoński, M. (2009). Wielokryterialna analiza decyzyjna w systemach GIS, Polskie Stowarzyszenie Zarządzania Wiedzą, Seria: Studia i Materiały, 18, 123–134.
- Prakash, C., Barua, M.K. (2016). A Combined MCDM approach for evaluation and selection of third-party reverse logistics partner for Indian electronics industry, Sustainable Production and Consumption, 7, 66-78. <https://doi.org/10.1016/j.spc.2016.04.001>
- Predrycz, W., Ekel, P., Parreiras, R. (2010). Fuzzy multicriteria decision-making: Models, Methods and Applications, John Wiley, New York.
- Ranjan, R., Chatterjee, P., Chakraborty, S. (2016). Performance evaluation of Indian Railway zones using DEMATEL and VIKOR methods, Benchmarking an International Journal, 23(1), 78-95. <http://dx.doi.org/10.1108/BIJ-09-2014-0088>
- Ren, P., Xu, Z., Gou, X. (2016). Pythagorean fuzzy TODIM approach to multi-criteria decision making, Applied Soft Computing, 42, 246-259. <https://doi.org/10.1016/j.asoc.2015.12.020>
- Saaty, T. L. (1977). A Scaling Method for Priorities in Hierarchical Structures, Journal of Mathematical Psychology, 15(3), 234-281. [https://doi.org/10.1016/00222496\(77\)90033-5](https://doi.org/10.1016/00222496(77)90033-5)
- Sarkis, J. (2003). A strategic decision making framework for green supply chain management, Journal of Cleaner Production, 11(4), 397-409. [http://dx.doi.org/10.1016/S0959-6526\(02\)00062-8](http://dx.doi.org/10.1016/S0959-6526(02)00062-8)
- Skinner, J. K. (2015). Bibliometric and social network analysis of doctoral research: Research trends in distance learning, The University of New Mexico, Doctor of Philosophy, Organization Information and Learning Sciences, Albuquerque, New Mexico.
- Singh, S., Olugu, E.U., Musa, S.N., Mahat, A.B., Wong, K. Y. (2016). Strategy selection for sustainable manufacturing with integrated AHP-VIKOR method under interval-valued fuzzy environment, The International Journal of Advanced Manufacturing Technology, 84(1-4), 547-563. <https://doi.org/10.1007/s00170-015-7553-9>
- Sobczyk, E. J., Wota, A., Krezolek, S. (2011). Zastosowanie matematycznych metod wielokryterialnych do wyboru optymalnego wariantu źródła pozyskania węgla kamiennego, Gospodarka Surowcami Mineralnymi/Mineral Resources Management, 27, 51–68.

- Sofiyabadi, J., Kolahi, B., Valmohammadi, C. (2016). Key performance indicators measurement in service business: a fuzzy VIKOR approach, 27(9-10), 1028-1042. <https://doi.org/10.1080/14783363.2015.1059272>
- Trzaskalik, T. (2014a). Wielokryterialne wspomaganie decyzji, Metody i zastosowania, PWE, Warszawa.
- Trzaskalik, T. (2014b). Wielokryterialne wspomaganie decyzji, Przegląd metod i zastosowań, Zeszyty Naukowe Politechniki Śląskiej. Seria: Organizacja i Zarządzanie, 74, 239–263.
- VOSviewer (version 1.6.17, February 19, 2024). Centre for Science and Technology Studies, Leiden University, The Netherlands. <https://www.vosviewer.com>
- Wanga, L., Zhanga, H., Wanga, J., Li, L. (2017). Picture fuzzy normalized projection-based VIKOR method for the risk evaluation of construction Project, Applied Soft Computing, 64, 216-226. <https://doi.org/10.1016/j.asoc.2017.12.014>
- Xiong, L., Teng, C. L., Zhu, B. W., Tzeng, G. H., Huang, S. L. (2017). Using the D-DANP-mV Model to Explore the Continuous System Improvement Strategy for Sustainable Development of Creative Communities, *International Journal of Environmental Research and Public Health*, 14(11):130. <https://doi.org/10.3390/ijerph14111309>
- Yager, R. R. (2004). Modeling Prioritized Multicriteria Decision Making, IEEE Transactions on systems, Man, and Cybernetics, 34(6), 2396-2404.
- Yager, R. R. (2018). Categorization in multi-criteria decision making, Information Sciences, 460-461, 416-423. <http://dx.doi.org/10.1016/j.ins.2017.08.011>
- Yazdani, M., Zolfani, S. H., Zavadskas, E. K. (2016). New integration of MCDM methods and QFD in the selection of green suppliers. Journal of Business Economics and Management, 17(6), 1097–1113. <https://doi.org/10.3846/16111699.2016.1165282>
- Yu, Q., Hou, F. (2016). An approach for green supplier selection in the automobile manufacturing industry, Kybernetes, 45(4), 571-588. <https://doi.org/10.1108/K-01-2015-0034>
- Yu, D., Xu, Z., Wang, W. (2018). Bibliometric analysis of fuzzy theory research in China: A 30-year perspective, Knowledge-Based Systems, 141, 188-199. <http://dx.doi.org/10.1016/j.knosys.2017.11.018>
- Zadeh, L. A. (1965). Fuzzy sets. Information and Control, 8 (3), 338-353. [https://doi.org/10.1016/S00199958\(65\)90241-X](https://doi.org/10.1016/S00199958(65)90241-X)
- Zavadskas, E. K., Turskis, Z. (2011). Multiple criteria decision making (MCDM) methods in economics: an overview. Technological and Economic Development Economy, 17(2), 397-427. <https://doi.org/10.3846/20294913.2011.593291>
- Zyoud, S. H., Fuchs-Hanusch, D. (2017). A bibliometric-based survey on AHP and TOPSIS techniques. Expert Systems with Applications, 78, 158-181. <https://doi.org/10.1016/j.eswa.2017.02.016>
- Zopounidis, C., Doumpos, M. (2017). Multicriteria decision making: Applications in Management and Engineering, Springer, Heidelberg.

## ASSESSING THE INTERNAL CONTROLS IN LOCAL GOVERNMENTS IN GHANA

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Anthony Eygir Aikins<sup>1</sup>, John Victor Mensah<sup>2</sup>, Musah Dankwah<sup>3</sup>, Harriet Muriel Dzifa Potakey<sup>4</sup>

<sup>1</sup>Rigour Consult, Management Consulting, Cape Coast, Ghana.

[aeaikins@gmail.com](mailto:aeaikins@gmail.com), ORCID: 0000-0002-3595-0095

<sup>2</sup>University of Cape Coast, School for Development Studies, Cape Coast, Ghana.

[John.mensah@ucc.edu.gh](mailto:John.mensah@ucc.edu.gh), ORCID: 0000-0001-9132-2299

<sup>3</sup>University of Cape Coast, School for Development Studies, Cape Coast, Ghana.

[musah.dankwah@ucc.edu.gh](mailto:musah.dankwah@ucc.edu.gh), ORCID: 0000-0002-1242-6194

<sup>4</sup>University of Cape Coast, School for Development Studies, Cape Coast, Ghana.

[hpotakey@ucc.edu.gh](mailto:hpotakey@ucc.edu.gh), ORCID: 0000-0002-9513-2780

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### ABSTRACT

**Purpose** – Adequate internal control systems are prerequisites for efficient and effective operations of local governments but their mere presence does not guarantee efficiency and effectiveness. In Ghana, internal audit reports recount irregularities in operations resulting in the delivery of poor services and amenities to the communities. This study sought to assess the internal control systems in local governments to ascertain their effectiveness or otherwise. The institutional theory informed the study.

**Methodology** - The qualitative research approach was employed for the study. The purposive sampling technique was used to select 24 officers from six selected local governments in the Central Region of Ghana. In each local government, a Coordinating Director, an Audit Committee member, an Internal Auditor, and a Finance Officer were interviewed. Primary data were collected by the use of interview guide while secondary data were collected by document review guide. The secondary data were derived from literature on internal controls. The data was subjected to thematic analysis and interpretation.

**Findings** - The study revealed that management bodies of local governments have put in place the desired standard internal controls but there were irregularities in their operations, thereby leading to ineffective internal controls.

**Conclusion** - The internal controls of the selected local governments were similar to the standard controls. However, the implementation of internal controls did not result in propriety and soundness due to irregularities. It was recommended that relevant authorities should ensure adherence to internal controls in local governments.

**Keywords:** African communities, Operations, Internal audit reports, Local governments

**JEL Codes:** M41, M42, H83

### 1. INTRODUCTION

Institutions and organisations are established for a purpose; just as programmes and projects have objectives for which they are undertaken. These objectives need to be achieved to justify the efforts used to invest resources to set up the institutions and organisations. Most invariably, some of the persons who are responsible for the achievement of these objectives, try to exploit certain activities to their advantage. In such situations, the purpose for establishing institutions would, therefore, not be met. For the achievement of organisational objectives, effective measures are required to be established (Odunko, 2022), which aimed at minimising errors, omissions, wastes, purposeful acts, and frauds. The measures known as internal controls (Vulley, 2022) not only promote the adherence to norms and rules but also enhance institutional efficiency (Otoo, Kaur & Rather, 2023). This justifies the choice of institutional theory to assist in understanding the phenomenon under study.

The institutional theory explains that, in order for institutions such as the local governments to survive, the right measures or processes ought to be established and enforced to deal with pressures from both internal and external environments. Internal controls aid institutions to realise their objectives (Francis & Imiete, 2018; Hoai, Hung, & Nguyen, 2022). The effectiveness of the internal control systems implemented by institutions' management is a key factor in an entity's ability to survive (Chalmers, Hay, & Khelif, 2019; Musah, Padi, Okyere, Adenutsi, & Ayariga, 2022). Pham (2023) argues that having an effective internal control programme is mission-critical for ensuring long-term institutional progress; and institutions that invest resources and time in putting in place internal control systems are able to ensure compliance with laws, policies,

regulations, and other administrative instructions, and directives. In this study, purpose(s) and objective(s) as well as institution(s) and organisation(s) respectively had been used interchangeably.

Three anecdotal evidence inform the statement of the problem for this study. Firstly, local governments are seen as dishonest. Secondly, the people do not enjoy quality services. Thirdly, the internal controls in the local governments seem not to work to expectation. The main objective of this study was to assess the internal controls in local governments in Ghana. The specific objectives were to:

1. Compare the internal controls of the local governments with the standard internal controls for institutions.
2. Inquire into the effectiveness or otherwise of the internal controls of local governments.
3. Make recommendations for local governments to comply with the standard internal controls.

The significance of the study would enable stakeholders to know the adequacy of the internal controls in local governments. The originality of the study is the use of semi-structured interviews and the institutional theory to determine the effectiveness or otherwise of the internal controls in local governments. The practical implication is that local governments would continue to deliver poor quality services to the people if internal controls are not effective and do not meet the expectations of stakeholders. The study is structured on six sections. Section one deals with the introduction while sections two, three, and four cover literature review, methodology, and results and discussion respectively. The conclusion and recommendations are found in the fifth section while limitation of the study and suggestions for future research are presented in the sixth section.

## **2. LITERATURE REVIEW**

This section comprises three sub-sections reviewing internal controls, effects of the principles of the components of the COSO internal controls on institutions, and theoretical foundation of the study.

### **2.1. Internal Controls**

The establishment of internal controls in institutions has become crucial as a component of good corporate governance (Alfartoosi & Jusoh, 2021; Le *et al.*, 2020; Odek & Okoth, 2019). The changing competitive environment makes it more critical for internal controls to be implemented in the desired state to ensure the achievement of objectives (Nanzala & Ingabo, 2021; Omar & Yussuf, 2021). Internal controls enable local governments to improve operational efficiency by ensuring compliance with rules, regulations, and laws (Hazzaa, Abdullah, & Dhahebi, 2022; Johnston & Zhang, 2018). Several authors have definitions and meanings of internal controls but they all merge at the point where they ensure propriety and soundness in processes to achieve objectives.

While Pham (2023) explains internal controls as policies, procedures, and processes designed to safeguard assets and minimise risk while Kenton (2024) espouses that internal controls are the policies, guidelines, and practices that a business implements to guarantee the accuracy of its financial and accounting data, encourage responsibility, and thwart fraud. Kirkpatrick (2024) illuminates that internal controls as the procedures and processes that organisations ought to employ to safeguard assets and improve the accuracy of financial records.

On the other hand, in 2013, the Committee of the Sponsoring Organisations of the Treadway Commission (COSO) updated the COSO (1992) framework. It emphasised that internal control is a process carried out by an entity's board of directors, management, and other staff members that is intended to provide reasonable assurance regarding the achievement of objectives to ensure effectiveness and efficiency of operations, reliability of financial reporting, and compliance with applicable laws and regulations. COSO (2013) delivered a compromise definition to embrace a common understanding of internal controls among stakeholders such as legislators, regulators, academics, professionals, corporate management, internal and external auditors, and the general public. This was after the committee was originally charged with the responsibility to investigate the fraud scandals of the 1970s and 1980s.

According to the COSO (2013), management organisations are in charge of establishing and upholding internal controls in institutions. This has been corroborated by Nicholls State University (2024) which asserts that the establishment of internal controls is the responsibility of management. According to Financial Executives International (2024), the American Accounting Association, the American Institute of Certified Public Accountants, Financial Executives International, the Institute of Internal Auditors, and the Institute of Management Accountants are the five private sector organisations that collaborated to create the COSO. It further stated that COSO is committed to leading by example by creating frameworks and guidelines for internal controls, fraud deterrence, and enterprise-wide risk management. As a result, COSO created an internal control framework that became known as the COSO framework, also known as the COSO Internal Control-Integrated Framework (Leland, 2023).

Leland (2023) explains that the COSO framework offers recommendations on how organisations can put internal controls in place to stop, identify, and handle fraud risk in financial reporting-related scenarios. Kirkpatrick (2024) observes that the COSO framework is an industry-standard model for assessing and implementing internal control systems within organisations, making the COSO an authority on the topic of internal controls. It is, therefore, appropriate to use the principles of the

components of COSO (2013) framework as the standard internal controls to be used by institutions, generally. The COSO framework is made up of five main components and 17 principles with supporting 87 points of focus. The five components are control environment, risk assessment, control activities, information and communication, and monitoring. Each of the five components has its respective principles as shown in Table 1.

**Table 1: COSO Internal Control Integrated Framework showing the Components and their Respective Principles**

No.	Control Environment	Risk Assessment	Control Activities	Information and Communication	Monitoring
1.	Demonstrating commitment to integrity and ethical values	Specifying suitable objectives	Selecting and developing control activities	Using relevant information	Conducting ongoing and/or separate evaluations
2.	Exercising oversight responsibility	Identifying and analysing risk	Selecting and developing general controls over technology	Communicating internally	Evaluating and communicating deficiencies
3.	Establishing structure, authority, and responsibility	Assessing fraud risk	Deploying through policies and procedures	Communicating externally	-
4.	Demonstrating commitment to competence	Identifying and analysing significant change	-	-	-
5.	Enforcing accountability	-	-	-	-

The control environment is made up of the management bodies' philosophy and operating style, the competences of the employees, morale, integrity, and ethical values among others (Chen, Yang, Zhang & Zhou, 2020; Gao & Zhang, 2019). It is the foundation for all the other internal controls (Chalmers *et al.*, 2019; Vu & Nga, 2022). The control environment ensures discipline and order and improves the quality of the system in place (Chiu & Wang, 2019; Peterson, 2018). It demonstrates management bodies' dedication to ethical practices by enhancing employee behaviour and institutional performance (Gal & Akisik, 2020).

The process of determining and assessing threats to institutional objectives is known as risk assessment (Chen *et al.*, 2020). Managing risks is essential for effective institutions (Chiu & Wang, 2019; Musah *et al.*, 2022). Thus, risk assessment aids in setting priorities for particular goals that affect an organisation's internal control systems (Hamdan, 2019).

The control activities are procedures and policies that management bodies put in place to ensure the implementation of administrative instructions and directives (Adegboyegun, Ben-Caleb, Ademola, Oladutire, & Sodeinde, 2020; Le *et al.*, 2020). According to GamageLow and Keving (2018), institutions accomplish their objectives through the establishment of control activities and being compliant thereof. Chalmers *et al.* (2019) underscore that management bodies should take into account the features and functions of the institutions as well as the control environment when choosing and implementing control activities. However, Chang *et al.* (2019) suggest that management bodies should evaluate and scrutinize the control efforts to make sure they remain relevant.

Within institutions, information is disseminated through processes of communication and information (Frazer, 2020; Vu & Nga, 2022). According to Hamdan (2019), good communication transcends the boundaries of institutions and that the resilience and quality of the control environment are reflected in the information and communication effectiveness within institutions (Bruwer, Coetzee & Meiring, 2018). On the other hand, Peterson (2018) contends that a reliable information and communication system gives stakeholders accurate information.

The monitoring component involves evaluating how well an institution's control systems are operating (Wali & Masmoudi, 2020). Frequent evaluations for effectiveness and efficiency are essential for assessing an institution's internal control system (Crosman, 2018); while monitoring procedures assess the quality of the implemented controls and how well they manage risks (Dowdell, Klamm & Andersen, 2020).

## 2.2. Effects of the Principles of the Components of the COSO Internal Controls on Institutions

The effects of the principles of the control environment on institutions are that where the internal controls are effective there would be discipline and order. Institutions would go about their duties as expected and objectives are expected to be achieved. On the other hand, ineffective internal controls breed indiscipline, and derail morale, integrity and ethical values. The likelihood that the other components would fail to achieve the objectives for which they were established would be high because the control environment forms the basis for establishing the other components (Chalmers *et al.*, 2019; Vu & Nga, 2022).

With regard to the effects of the principles of the risk assessment on institutions, institutional objectives would be achieved where risks are properly identified, assessed, and managed. On the contrary, poorly identified risks and improper evaluation of impacts would promote financial losses and reputational damage due to fraud, loss of assets, trust, and credibility among stakeholders. Other operational, regulatory, and legal consequences such as operational disruptions, and sanctions would also affect the achievement of objectives (Chiu & Wang, 2019; Hamdan, 2019; Chen *et al.*, 2020; Musah *et al.*, 2022).

The effects of the principles of the control activities on institutions are that where policies and procedures are implemented effectively, there would be adequate checks in institutions to forestall incidences of inefficiencies, waste, and other untoward actions and inactions that would prevent achieving objectives. Processes in institutions would conform to standard. In situations where policies, rules, and regulations are disregarded, operations of institutions would be fraught with irregularities and waste (Adegboyegun *et al.*, 2020; Le *et al.*, 2020).

The effects of the principles of the information and communication on institutions are that where information is communicated across institutions and well disseminated, there would be goal-congruence and everybody would perform to achieve the goals and objectives of institutions. Employees would work with satisfaction as there would be transparency in operations. Conversely, where there is misinformation, people would not be effective on their responsibilities as no clear instructions and directives could be given; but where disinformation is perpetrated, then objectives could not be achieved. Fraudulent activities would be rife as there would not be discipline and order (Frazer, 2020; Peterson, 2018).

Some of the possible effects of the principles of the monitoring on institutions are that where continuous evaluation becomes part of the system in place, deviations in operations would be captured and appropriate control measures put in place to restore sanity in processes. Objectives would then be achieved and institutions would live up to expectation. In situations where there is little monitoring or no proper arrangement put in place to enforce frequent monitoring and evaluations, there would be lapses in operations which may result in fraudulent activities, misuse of resources, and loss of trust and confidence in institutions. Irregularities would persist in the operations of institutions (Wali & Masmoudi, 2020; Crosman, 2018). The preceding effects explain, to a large extent, when there ought to be propriety and soundness in operations and vice versa. It is, therefore, expected that the effects of the internal controls of local governments would yield propriety and soundness in operations.

The AuditBoard (2021) provides six steps that an institution can audit its processes with the internal controls in place:

1. The framework containing the internal controls ought to be confirmed as emanating from the management bodies.
2. The internal controls ought to be aligned with that of the standard controls.
3. Performing gap analysis by noting the differences in the alignment process.
4. Documenting the control design gaps and discussing with management bodies who ought to put in place corrective plans of action to deal with the gaps.
5. Testing the effectiveness of the controls put in place by management after noting the gaps
6. Monitoring progress on management's corrective action plans.

Kirkpatrick (2024) notes that as soon as it is discovered that an institution is not compliant with the standard controls, there ought to be an assessment to identify the areas and understand the underlying reasons. After that, remediation plan is developed while the new changes are implemented followed by monitoring and documenting the progress of the changes. Where necessary, an external expertise is sought.

According to Pham (2023), everyone is accountable for ensuring that internal controls are implemented and maintained effectively, even though management bodies are in charge of doing so. Every employee in an organisation has a crucial responsibility to maintain a strong internal control environment that safeguards property, guarantees the accuracy and completeness of records, complies with legal requirements, promotes operational effectiveness, and aids in the achievement of corporate goals through effective risk management.

The effective functioning of the internal controls rests on the shoulders of everyone in institutions who seeks to achieve the objectives but it does not change the narrative that the management bodies have the responsibility to establish and maintain effective internal controls (Pham, 2023). Thus, management bodies of local governments are empowered to put in place adequate internal control systems. Weak internal controls undermine the integrity of processes in local governments. In such situations, local governments would not be seen to perform to expectation and poor quality of municipal services and amenities would be the end products delivered.

The local governments in Ghana are referred to as Assemblies and have been categorised into three; namely, metropolitan, municipal, and district. This qualifies the local governments as either, a Metropolitan, Municipal, or a District Assembly; and also known as the MMDAs. The local governments represent the central governments in their respective localities. Therefore, their performance reflects that of the central governments'. The central governments would either earn the praise of the

people if local governments' performance is good or incur the displeasure of the people where their performance is poor. The popularity or otherwise of central governments is, therefore, contingent upon the level of performance exhibited by the local governments. It is as a consequence of this that respective central governments decide to commission the activities of internal auditing in local governments to inspect and examine their operations and provide the desired feedback on internal controls through periodic reports. The effectiveness of the internal controls would then be at the point where the objective(s) for establishing the controls have been achieved. Otoo (2019) emphasises that internal control systems enhance operational efficiency, effectiveness, and competitive advantage.

### **2.3. Theoretical Foundation of the Study**

The study is underpinned by the institutional theory. The theory posits that organisations survive because structures and laid down procedures have been firmly established and enforced rigidly (Meyer & Rowan, 1977; Scott, 2005). Based on an essential principle of the institutional theory, organisations endure pressure to homogenize (DiMaggio & Powell, 1983). Organisations are influenced by both internal and external forces in support of the applicability of this fundamental premise (Scott, 1987; Zucker, 1987). External pressures include laws, professional conventions, and codes of ethics; internal pressures are made up of formalised arrangements like policies, schemes, conventions, and procedures in organisations.

The institutional theory explains the idea of internal control by pointing out how external constraints force institutions to follow set procedures and standards. The internal controls, which ensure that there is discipline and structure, influence processes in local governments; and by extension, the quality of amenities delivered to the local level. The internal controls would determine the quality and level of responsiveness of local governments. The need for internal controls in local governments is as relevant today as it was in the days of yore.

## **3. METHODOLOGY**

This section covers research design, study areas, sampling technique and sample size, data collection instruments, data collection instruments, ethical considerations, and data analysis.

### **3.1. Research Design**

The research design offers a rational method for gathering empirical data to address research questions and aids in deriving conclusions from the investigation (Romanchuk, 2023). It accounts for the selection of the right methodology, choosing appropriate data collection methods, and coming up with appropriate framework for analysing the data. The qualitative research approach was used for the study to understand in depth, the phenomena of the study; in order to concentrate efforts on evaluating the richness of the data rather than collecting numerical data.

### **3.2. Study Areas**

Six local governments constituting the study area were the Cape Coast Metropolitan Assembly, Komenda-Edina-Eguafo-Abrem Municipal Assembly, Mfantseman Municipal Assembly, Abura-Asebu-Kwamankese District Assembly, Ekumfi District Assembly, and Gomoa West District Assembly. The number of local governments in the Central Region in 2022 was 22, which was made up of one metropolitan assembly, seven municipal assemblies, and 14 district assemblies. In order to collect the data to cut across the structure of the local government areas in the region (Figure 1), one metropolitan assembly, two municipal assemblies, and three district assemblies were selected.

The profile of the study local government areas is presented in Table 2. The Gomoa West District has the largest land size with the third lowest population and the second lowest population density while Cape Coast Metropolis has the lowest land size but the highest population and population density. The Cape Coast Metropolis, which serves as the capital of the Central Region of Ghana, has two universities. The economic activities of the local governments are almost the same with some slight differences. Fishing is practised in the coastal communities in local government areas along the Gulf of Guinea. Salt-making is practised in the KEEA Municipality, Gomoa West District and Ekumfi District.

Figure 1: Map of metropolis, municipalities and districts in the Central Region of Ghana



Source: Office of the Head of Local Government Service (2020)

### 3.3. Sampling Technique and Sample Size

Four participants from each of the six local governments formed the sample size of 24, which was selected using the purposive sampling technique. The four participants were the Coordinating Director, Audit Committee member, Internal Auditor, and Finance Officer. This means that four Coordinating Directors, four Audit Committee members, four Internal Auditors, and four Finance Officers were selected from the six local government for the study. The reason for using the purposive sampling technique was that there was the need for the researchers to use appropriate judgement as espoused by Saunders, Lewis and Thornhill (2012) to identify and select participants that could provide relevant data to support the study. Creswell (1998) recommended a sample size of five to 25 participants for a qualitative study while Morse (1994) indicated at least six participants; with Subedi (2021) settling on one to 20 or more participants with adequate justification. Therefore, the sample size of 24 was adequate for the study.

Table 2: Spatial, Demographic and Economic Profile of the Study Area

Study Area	Land size (km <sup>2</sup> )	Population	Population density (km <sup>2</sup> )	Name of University	Major economic activities
Cape Coast Metropolis	122	189,925	1556.8	(i) University of Cape Coast, (ii) Cape Coast Technical University	Fishing, peasant farming, commerce, public service, tourism
Komenda-Edina-Eguafo-Abrem Municipality	372	166,017	446.3	-	Fishing, peasant farming, commerce, public service, salt-making, tourism
Mfantseman Municipality	314.4	168,905	537.2	-	Fishing, peasant farming, commerce, public service
Abura-Asebu-Kwamankese District	386.4	124,465	322.1	-	Peasant farming, commerce, public service
Gomoa West District	456.1	129,512	284.0	-	Fishing, peasant farming, salt-making, commerce, public service
Ekumfi District	270.3	56,741	209.9	-	Fishing, peasant farming, salt-making, commerce, public service

Source: Ghana Statistical Service (2021)

### 3.4. Data Collection Instruments

Using interview guides and document review guides, primary data were gathered. The literature on internal controls served as the secondary data. The interviews were conducted on phone in order to cut down on traveling expenses as the researchers were on low budget. Two trained research assistants conducted the interviews. They introduced themselves as research assistants who were collecting data on the internal controls in local governments in the Central Region for an academic exercise. They asked permission for the interviews to be tape-recorded. The participants were informed of their liberty to excuse themselves from further interview if they so desired. The participants were further assured of anonymity.

The 2013 COSO internal control integrated framework's component principles served as the foundation for the interview guide's questions. In some cases, follow-up questions were asked to clarify the responses. The participants were given the opportunity to explain themselves in whatever manner that they wished; and they were also allowed to ask questions to satisfy their curiosity.

### 3.5. Ethical Considerations

Before the interviews began and the subsequent tape recording, the participants were requested for their verbal informed consent. The participants were further assured of confidentiality, anonymity, and privacy. They were made aware that they could excuse themselves from further interview at any time they wanted. Each interview session concluded with a thank-you to the participants for their availability. Due to anonymity to protect the identity of participants, the analysis was not made according to local government institutions.

### 3.6. Data Analysis

The data collected were coded and subjected to thematic analysis and interpretation to ensure consistency and transparency. The principles of the components of the 2013 COSO internal controls on institutions were used as the standard themes. The data on the internal controls of the local governments were read over to check omissions and corrections. The identified themes represented the internal controls of the selected local governments. Firstly, the two sets of themes were compared to address the first specific objective. Secondly, the outcome of the effects of the standard internal controls on the operations of institutions dealing with propriety and soundness were used as the standard to determine the outcome of the effects of the internal controls of local governments on their operations. This was determined by examining and interpreting the responses given by the participants. In situations where the responses indicated that there were propriety and soundness in operations of the selected local governments, then the internal controls were effective. In contrast, where the responses indicated that there were no propriety and soundness in operations of local governments, then the internal controls were ineffective.

## 4. FINDINGS AND DISCUSSION

This section is based on the first two specific objectives of the study.

### 4.1. Comparing the Internal Controls of the Local Governments with the Standard Internal Controls

The study revealed that the internal controls that had been put in place in the local governments were the same as the standard controls by COSO (2013) presented in Table 1. This is evidenced by the responses of five participants as follows:

*As for the internal controls, they are the same as that of the standard ones; but their implementation is the issue (an Internal Auditor, 17<sup>th</sup> November, 2022).*

*The internal controls we have on paper are fantastic. They correspond to that of the standard controls (an Audit Committee member, 13<sup>th</sup> October, 2022).*

*The internal control system in place is very adequate and conforms to the COSO internal control integrated framework (an Internal Auditor, 25<sup>th</sup> August, 2022).*

*We have adequate internal controls in place; and they can be compared to the standard framework (a Coordinating Director, 24<sup>th</sup> August, 2022).*

*The last time that the district auditors came for their audit inspection, they remarked that our control framework is standard but we need to implement them to the letter (a Finance Officer, 31<sup>st</sup> August, 2022).*

The finding implies that the local governments were expected to perform to ensure operational efficiency. Services delivered by the local governments were expected to meet the expectation of the people to enhance their living conditions at the local level. The finding is also consistent with the principles of the institutional theory as the processes and procedures were followed by putting in place the desired internal controls in the local governments to guarantee discipline in operations.

## 4.2. Effectiveness of the Internal Controls of Local Governments

The data indicated that the internal controls that had been established in the local governments were not effective because there were inefficiencies and disregard for operational norms and procedures. These have been explained by various issues as reported by the key informants. Four key informants recounted disregard for operational norms as follows:

*The internal controls in this Assembly are not working; that is all I can say* (Internal auditor, 23<sup>rd</sup> September, 2022).

*What do you mean by internal control? They don't belong here* (a Finance Officer, 12<sup>th</sup> December, 2022).

*I understand internal controls to mean the policies and regulations that everybody should follow but, in this assembly, there is nothing like that* (a Finance Officer, 18<sup>th</sup> August, 2022).

*I cannot say that the internal controls in this assembly are effective because everybody does what he or she likes* (an Internal Auditor, 16 December, 2022).

The above comments suggest that such disregard for the internal controls shows disrespect for institutional policies, which would hinder productivity.

Two participants stated that some members of staff who were expected to cooperate in the local government system are not implementing the internal controls to promote effectiveness:

*Internal controls are implemented by people, so if the people themselves don't follow the rules; then what happens?* (an Audit Committee member, 1<sup>st</sup> August, 2022).

*There is indiscipline in this Assembly. The internal controls are weak and ineffective* (a Coordinating Director, 29<sup>th</sup> November, 2022).

The comments by the foregoing key informants suggest that internal controls were not being implemented to expectation. The reasons might be due to management flaws, impunity, no discipline, nepotism, incompetence of staff, and non-application of sanctions. Even though it appeared that the staff were not performing their roles; it was the responsibility of management bodies to establish internal controls and ensure their effective implementation. Therefore, the management bodies were not performing their expected roles of enforcement.

Two participants explained the ineffectiveness in terms of not safeguarding equipment and financial resources of the Assemblies as remarked as follows:

*Vehicles and laptops continue to get missing. Do you think if the controls are effective, these things will happen* (an Internal Auditor, 26<sup>th</sup> October, 2022).

*Revenue collectors embezzle revenues collected; and the same people who are to check and punish them are seen moving about with them. There is no effective internal controls in place* (a Finance Officer, 20<sup>th</sup> November, 2022).

Stealing vehicles and laptops, and embezzling revenues reduce the Assemblies' resources for developing the communities. These are issues of negligence, accountability, record-keeping, collusion, and inefficient supervision.

Another issue of ineffectiveness leading to low productivity was employing unqualified people as expressed by a participant as follows:

*Instead of employing qualified personnel, they employ their friends who don't know anything* (a Coordinating Director, 15<sup>th</sup> October, 2022).

Such employment would breed nepotism, incompetence, and corruption in personnel recruitment, and undermine progress. Poor performance of unqualified staff would not achieve the objectives of the Assembly. The finding is consistent with that Aikins, Mensah, and Essaw (2024) that because established protocols were not followed, the management bodies' working philosophies and styles did not serve the goals of local governments.

Another participant related ineffectiveness to procurement breaches by recounting as follows:

*People do not follow procedures to purchase items, so some of the suppliers don't supply all the items ordered* (an Internal Auditor, 29<sup>th</sup> October, 2022).

Procurement breaches would lead to mismanagement of resources, no value for money, wastage and inefficiencies as well as poor community development.

Two participants explained that those who flouted the internal controls not sanctioned:

*There are internal controls in place but we are not in a position to sanction those who flout them (a Coordinating Director, 17<sup>th</sup> November, 2022).*

*At Audit committee meetings we emphasise on the need to follow laid down instructions and policies but the results are the same. No concrete action taken against those who go against the rules (an Audit Committee member, 30<sup>th</sup> October, 2022).*

Sanctions are part of internal controls. Non-enforcement of sanctions would encourage people continue to disobey regulations to the detriment of the Assembly. In some cases, it would mean a breakdown of discipline and order, which would undermine community development and living conditions of the people.

Political interference breeding discrimination, disrespect and bad mood in the Assemblies was another cause of ineffectiveness as expressed below:

*We sometimes get instructions from above and we can't do anything about it. When this situation continues, then no objective would be achieved in this Assembly (a Coordinating Director, 13<sup>th</sup> September, 2022).*

For a Coordinating Director, who occupies the highest administrative position of the Assembly, talk of receiving instructions from above means there was political interference. This would lead to power relations (i.e. boss and subordinate relationships) that would not augur well for cordial and peaceful co-existence of staff, thereby undermining the mandate of the Assemblies to perform in the interest of the people.

A key informant was of the opinion that there was lawlessness as explained below:

*Some Assembly officers go to do demolitions in town without any instruction or order but no action is taken against them (an Audit Committee member, 11<sup>th</sup> December, 2022).*

This situation would not augur well for the Assembly processes as it often creates confusion, disorder, and non-achieved objectives. The act of indiscipline without sanctions could be due to building of unauthorized structures, delays in approving permits, and irresponsible citizenship leading to illegal destruction of citizens' properties. Misunderstanding, anarchy and poor environmental management could occur when both the Assembly staff and the citizenry blatantly disregard the laws, regulations and rules. Collateral damages and poor living conditions may occur at the local areas.

The findings of the research are in line with those of Aikins and Mensah (2023) that operational inconsistencies exist in local governments despite internal auditing being conducted. However, they contradict the claims made by Hoai et al. (2022), Omar and Yussuf (2021), and Otoo (2019) that internal control mechanisms enhance operational effectiveness, efficiency, and competitive advantage in as well as protecting assets of an organisation and improving financial and operational performance.

In situations, where the effects of weak and ineffective internal controls are manifested in fiscal imprudence, misuse of resources, and wastage of assets, local governments are unable to deliver municipal services and other amenities in the communities. The findings of the research did not align with the tenets of the institutional theory, which established rules, regulations, laws, and directives that institutions should adhere to.

## **5. CONCLUSION AND RECOMMENDATIONS**

The paper has provided evidence that the internal controls of the selected local governments were similar to the standard controls comprising five components and 17 principles with 87 points of focus. The five components were control environment, risk assessment, control activities, information and communication, and monitoring. However, the controls were weak and ineffective as manifested by several irregularities which impeded propriety and soundness to achieve the required objectives of the Assemblies. The irregularities included disregard for operational norms, laws, regulations and rules; management flaws; negligence; employment of unquantified people; procurement breaches; and non-enforcement of sanctions.

Based on the conclusion, the following recommendations are made:

1. The Office of the Head of the Local Government Service (OHLGS) should commend management bodies of local governments for putting in place standard internal controls and encouraging them to continue to act same.
2. OHLGS should prevail on management bodies to comply with the internal controls that have been put in place in local governments to strengthen transparency and accountability initiatives.
3. OHLGS should sanction management bodies for not complying with the internal controls of the local governments in their operations.

4. The Auditor-General's Office should evaluate the existing oversight mechanisms to strengthen the capacity of its field personnel to deal with the gaps in transparency and accountability in the processes of local governments.
5. OHLGS should develop capacity-building programmes for the local government officials based on their areas of weaknesses.
6. OHLGS should enforce community participation in the activities of the local governments.
7. The perpetrators of these vices need to be punished severely by the relevant law enforcement agencies to serve as deterrent to others who have similar motives.

## 6. LIMITATION OF THE STUDY AND SUGGESTIONS FOR FUTURE RESEARCH

The findings cannot be generalized due to the use of small sample associated with qualitative research such as this. They are limited to the six selected local governments. In essence, qualitative research focuses on understanding and analysing situations rather than gathering representative data (Delmar, 2010). With caution, the findings of this study can be generalised to all LGs. This work proposes that the mixed methods technique could be used in future research.

## REFERENCES

- Adegboyegun, A. E., Ben-Caleb, E., Ademola, A. O., Oladutire, E. O., & Sodeinde, G. M. (2020). Internal control systems and operating performance: Evidence from small and medium enterprises (SMEs) in Ondo state. *Asian Economic and Financial Review*, 10(4), 469-479. <https://archive.aessweb.com/index.php/5002/article/view/1937>.
- Aikins, A. E., & Mensah, J. V. (2023). Internal auditing and institutional performance of local governments in Ghana, *Indonesia Auditing Research Journal*, 12(3), 134-142. <https://journals.iarn.or.id/index.php/ARJ/article/view/204>.
- Aikins, A. E., Mensah, J. V., & Essaw, D. W. (2024). Risk management and control pitfalls of local governments in Ghana, *Indonesia Auditing Research Journal*, 13(1), 29-39. <https://journals.iarn.or.id/index.php/ARJ/article/view/215>.
- Alfartoosi, A., & Jusoh, M. A. (2021). A conceptual model of e-accounting: Mediating effect of internal control system on the relationship between e-accounting and the performance in the small and medium enterprises. *International Journal of Economics and Management Systems*, 6, 228-252. [https://www.researchgate.net/publication/343282124AConceptualModel\\_of\\_E-accounting\\_Mediating\\_effect\\_of\\_Internal\\_Control\\_System\\_on\\_the\\_Relationship\\_Between\\_E-accounting\\_and\\_the\\_Performance\\_in\\_the\\_Small\\_and\\_Medium\\_Enterprises](https://www.researchgate.net/publication/343282124AConceptualModel_of_E-accounting_Mediating_effect_of_Internal_Control_System_on_the_Relationship_Between_E-accounting_and_the_Performance_in_the_Small_and_Medium_Enterprises)
- AuditBoard (2021). Auditing with COSO, COBIT, and ISO Control Frameworks. <https://www.auditboard.com/blog/auditing-control-frameworks-cobit-coso-iso>.
- Bruwer, J. P., Coetzee, P., & Meiring, J. (2018). Can internal control activities and managerial conduct influence business sustainability? A South African SMME perspective. *Journal of Small Business and Enterprise Development*, 25(5), 710-729. <https://digitalknowledge.cput.ac.za/handle/11189/7198>.
- Chalmers, K., Hay, D., & Khlif, H. (2019). Internal control in accounting research: A review. *Journal of Accounting Literature*, 42, 80-103 <https://www.emerald.com/insight/content/doi/10.1016/j.acclit.2018.03.002/full/html>.
- Chang, Y. T., Chen, H., Cheng, R. K., & Chi, W. (2019). The impact of internal audit attributes on the effectiveness of internal control over operations and compliance. *Journal of Contemporary Accounting & Economics*, 15(1), 1-19. <https://www.sciencedirect.com/science/article/abs/pii/S1815566918301589>.
- Chen, H., Yang, D., Zhang, X., & Zhou, N. (2020). The moderating role of internal control in tax avoidance: Evidence from a COSO-based Internal Control Index in China. *The Journal of the American Taxation Association*, 42(1), 23-55. [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=3300188](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3300188).
- Chiu, T., & Wang, T. (2019). The COSO framework in emerging technology environments: An effective in-class exercise on internal control. *Journal of Emerging Technologies in Accounting Teaching Notes*, 16(2), 1-10. [https://www.researchgate.net/publication/334780790\\_The\\_COSO\\_Framework\\_in\\_Emerging\\_Technology\\_Environments\\_An\\_Effective\\_In-Class\\_Exercise\\_on\\_Internal\\_Control](https://www.researchgate.net/publication/334780790_The_COSO_Framework_in_Emerging_Technology_Environments_An_Effective_In-Class_Exercise_on_Internal_Control).
- Committee of Sponsoring Organization of the Treadway Commission. (COSO) (2013). The updated COSO internal control framework, New York: AICPA. <https://us.aicpa.org/interestareas/businessindustryandgovernment/resources/riskmanagmentandinternalcontrol/coso-integrated-framework-project>
- Committee of Sponsoring Organisations of the Treadway Commission (COSO) (1992). The Internal Control-Integrated Framework, New York: American Institute of Certified Public Accountants. Available at: [https://www.google.com/search?q=Committee+of+Sponsoring+Organisations+of+the+Treadway+Commission+\(COSO\)+\(1992\).+The+Internal+Control+Integrated+Framework%2C&og=Committee+of+Sponsoring+Organisations+of+the+Treadway+Commission+\(COSO\)+\(1992\).+The+Internal+Control+Integrated+Framework%2C&gs\\_lcrp=EgZjaHJvbWUyBggAEEUYOTIGCAEQRRg70qEJmzQ3MmowaiE1qAIIIsAIB&sourceid=chrome&ie=UTF-8](https://www.google.com/search?q=Committee+of+Sponsoring+Organisations+of+the+Treadway+Commission+(COSO)+(1992).+The+Internal+Control+Integrated+Framework%2C&og=Committee+of+Sponsoring+Organisations+of+the+Treadway+Commission+(COSO)+(1992).+The+Internal+Control+Integrated+Framework%2C&gs_lcrp=EgZjaHJvbWUyBggAEEUYOTIGCAEQRRg70qEJmzQ3MmowaiE1qAIIIsAIB&sourceid=chrome&ie=UTF-8).
- Creswell, J. W. (1998). *Qualitative inquiry and research design: Choosing among five traditions*, Thousand Oaks, CA: Sage Publications. <https://revistapsicologia.org/public/formato/cuali2.pdf>.

- Crosman, P. (2018). Could blockchain tech help prevent bank fraud. *American Banker*, 183(55), 1. Available at: <https://www.americanbanker.com/news/could-blockchain-tech-help-prevent-bank-fraud> (Accessed: 15/03/2022).
- Delmar, C. (2010). 'Generalisability' as recognition: reflections on a foundational problem in qualitative research, *Qualitative Studies*, 1(2), 115-128. <https://doi.org/10.7146/qs.v1i2.3828>.
- DiMaggio, P. J., & Powell, W. W. (1983). The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields. *American Sociology Review*, 48(2), 147-160. <https://www.istor.org/stable/2095101?origin=crossref>.
- Dowdell, T. D., Klamm, B. K., & Andersen, M. L. (2020). Internal controls and financial statement analysis. *Journal of Theoretical Accounting Research*, 15(2), 34-37. [https://scholar.google.com/citations?view\\_op=view\\_citation&hl=en&user=uUJihMAAAAJ&citation\\_for\\_view=uUJihMAAAAJ:9yKSN-GCB0IC](https://scholar.google.com/citations?view_op=view_citation&hl=en&user=uUJihMAAAAJ&citation_for_view=uUJihMAAAAJ:9yKSN-GCB0IC).
- Financial Executives International (2024). COSO – FEI. <https://www.financialexecutives.org/Influence/Committees/Coso.aspx>
- Francis, S., & Imiete, B. U. (2018). Internal control system as a mechanism for effective fund management of universities in Bayelsa State, Nigeria. *Global Journal of Social Sciences*, 17(1), 77-91. <https://doi.org/10.4314/gjss.v17i1.8>.
- Frazer, L. (2020). Does internal control improve the attestation function and by extension assurance services? A practical approach. *Journal of Accounting and Finance*, 20(1). <https://doi.org/10.33423/jaf.v20i1.2739>.
- Gal, G., & Akisik, O. (2020). The impact of internal control, external assurance, and integrated reports on market value. *Corporate Social Responsibility and Environmental Management*, 27(3), 1227-1240. doi/abs/10.1002/csr.1878.
- GamageLow, C. T., & Keving, L. T. (2018). Impact of internal control components and effectiveness of internal control system with the moderating effect of corporate governance of peoples' bank in Sri Lanka. *International Journal of Accounting and Taxation*, 6(2), 64-71. [https://ijat.thebrpi.org/journals/ijat/Vol\\_6\\_No\\_2\\_December\\_2018/7.pdf](https://ijat.thebrpi.org/journals/ijat/Vol_6_No_2_December_2018/7.pdf)
- Gao, P., & Zhang, G. (2019). Accounting manipulation, peer pressure, and internal control. *Accounting Review*, 94(1), 127-151. <https://doi.org/10.2308/accr-52078>
- Ghana Statistical Service (2021). Ghana 2021 Population and Housing Census: Population of Regions and Districts, Accra: Ghana Statistical Service. Available at: <https://census2021.statsghana.gov.gh/>
- Hamdan, K. H. (2019). Applying COSO internal control framework to disaster management: Evaluation according to hyogo framework for action (HFA) in Iraq. *Muthanna Journal of Administrative and Economic Sciences*, 9(2), 125-152. <https://muthiaes.mu.edu.iq/ar/applying-coso-internal-control-framework-to-disaster-management-evaluation-according-to-hyogo-framework-for-action-hfa-in-iraq-2/>
- Hazzaa, O. T., Abdullah, D. F., & Dhahebi, A. M. (2022). Review on the role of corporate governance and internal control system on firms' financial performance. *Asian Journal of Accounting Perspectives*, 15(1), 1-28. <https://ajap.um.edu.my/index.php/AJAP/article/view/27846>.
- Hoai, T. T., Hung, B. Q., & Nguyen, N. P. (2022). The impact of internal control systems on the intensity of innovation and organizational performance of public sector organizations in Vietnam: The moderating role of transformational leadership. *Heliyon*, 8(2), e08954. [https://www.cell.com/heliyon/fulltext/S2405-8440\(22\)00242-0?return](https://www.cell.com/heliyon/fulltext/S2405-8440(22)00242-0?return)
- Johnston, J. H., & Zhang, J. H. (2018). Information technology investment and the timeliness of financial reports. *Journal of Emerging Technologies in Accounting*, 15(1), 77-101. <https://digitalcommons.memphis.edu/facpubs/10912/>
- Kenton, W. (2024). Internal controls: definition, types, and importance. <https://www.investopedia.com/terms/i/internalcontrols.asp>
- Kirkpatrick, J. (2024). Five Internal control components using COSO Principles. <https://kirkpatrickprice.com/video/5-components-internal-control/>
- Le, N. T., Vu, L. T., & Nguyen, T. V. (2020). The use of internal control systems and codes of conduct as anti-corruption practices: Evidence from Vietnamese firms. *Baltic Journal of Management*, 16(2), 173-189. <https://doi.org/10.1108/BJM-09-2020-0338>.
- Leland, A. (2023). Fundamentals of the COSO Framework: Building Blocks for Integrated Internal Controls. <https://www.auditboard.com/blog/coso-framework-fundamentals/>
- Meyer, J. W., & Rowan, B. (1977). Institutional organisations: Formal structure as myth and ceremony, *American Journal of Sociology*, 83(2), 340-363. [http://www.ccsa.ufpb.br/gets/contents/documentos/meyer\\_rowan\\_teorias\\_institucional.pdf](http://www.ccsa.ufpb.br/gets/contents/documentos/meyer_rowan_teorias_institucional.pdf).
- Morse, J., M. (1994). Designing funded qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2<sup>nd</sup> ed.) (pp. 220-235), Thousand Oaks, CA: Sage. <https://www.scirp.org/reference/ReferencesPapers?ReferencelD=928823>
- Musah, A., Padi, A., Okyere, B., Adenutsi, D. E., & Ayariga, C. (2022). Does corporate governance moderate the relationship between internal control system effectiveness and SMEs financial performance in Ghana? *Cogent Business and Management*, 9(1), 1-19. <https://www.tandfonline.com/doi/pdf/10.1080/23311975.2022.2152159>.
- Nanzala, L. I., & Ingabo, O. W. (2021). The effect of internal control on financial performance. *International Journal of Finance and Accounting*, 2(2), 9-12. <https://grandmarkpublishers.com/journals/31263Critique.pdf>.
- Nicholls State University (2024). Management's responsibility and internal controls. Internal Audit Department. <https://www.nicholls.edu/internal-audit-department/audit-process/%20managements-responsibility-internal-controls/>

- Odek, R., & Okoth, E. (2019). Effect of internal control systems on financial performance of distribution companies in Kenya. *Research Journal of Finance and Accounting*, 10(20), 11-32. [https://www.researchgate.net/publication/337088902\\_Effect\\_of\\_Internal\\_Control\\_Systems\\_on\\_Financial\\_Performance\\_of\\_Distribution\\_Companies\\_in\\_Kenya](https://www.researchgate.net/publication/337088902_Effect_of_Internal_Control_Systems_on_Financial_Performance_of_Distribution_Companies_in_Kenya).
- Odunko, S. N. (2022). Internal control and firm performance from selected firms in Nigeria (2015-2020). *International Journal of Innovative Finance and Economics Research*, 10(1), 68-80. <https://www.seahipublications.org/wp-content/uploads/2024/06/IJIFER-M-6-2022.pdf>.
- Office of the Head of Local Government Service (2020). Map of metropolis, municipalities and districts in the Central Region of Ghana. [https://gpe.m.wikipedia.org/wiki/File:Districts\\_of\\_the\\_Central\\_Region\(2012\).svg](https://gpe.m.wikipedia.org/wiki/File:Districts_of_the_Central_Region(2012).svg)
- Omar, F. S., & Yussuf, S. (2021). Effect of control environment on the financial performance of higher learning public institutions in Zanzibar. *International Journal of Scientific and Technical Research Engineering*, 6(3), 18-25. <https://www.iistre.com/Publish/6302021/754235568.pdf>.
- Otoo, F. N. K. (2019). Human resource development (HRD) practices and banking industry effectiveness. *European Journal of Training and Development*, 43(3/4), 250-271. <https://fardapaper.ir/mohavaha/uploads/2019/06/Fardapaper-Human-resource-development--HRD-practices-and-banking-industry-effectiveness-The-mediating-role-of-employee-competencies.pdf>.
- Otoo, F. N. K., Kaur, M., & Rather, N. A. (2023), Evaluating the impact of internal control systems on organizational effectiveness, *LBS Journal of Management & Research*, 21(1), 135-154. <https://doi.org/10.1108/LBSJMR-11-2022-0078>
- Peterson, A. N. (2018). Differences in internal control weaknesses among varying municipal election policies. *Journal of Accounting and Public Policy*, 37(3), 191-206. <https://www.sciencedirect.com/science/article/abs/pii/S0278425418300309>.
- Pham, K. (2023). The essential guide to internal audit and controls. <https://www.auditboard.com/blog/internal-audit-controls/>
- Romanchuk, J. (2023). Four types of research design - Everything you need to know. <https://blog.hubspot.com/marketing/types-of-research-design>
- Saunders, M., Lewis, P., & Thornhill, A. (2012). *Research Methods for Business Students*, Harlow: Pearson. 728pp. [https://books.google.com.gh/books/about/Research\\_Methods\\_for\\_Business\\_Students.html?id=u4ybBgAAQBAJ&rediresc=y](https://books.google.com.gh/books/about/Research_Methods_for_Business_Students.html?id=u4ybBgAAQBAJ&rediresc=y).
- Scott, W. R. (2005). Institutional Theory: Contributing to a Theoretical Research Program, in *Great minds in management: The process of theory Development*, pp. 460-484, Oxford: Oxford University Press. [https://www.researchgate.net/publication/265348080\\_Institutional\\_Theory\\_Contributing\\_to\\_a\\_Theoretical\\_Research\\_Program](https://www.researchgate.net/publication/265348080_Institutional_Theory_Contributing_to_a_Theoretical_Research_Program).
- Scott, W. R. (1987). The adolescence of institutional theory, *Administrative Science Quarterly*, 32(4), 493-511. <https://psycnet.apa.org/record/1988-31350-001>.
- Subedi, K., R. (2021). Determining the sample in qualitative research, *Scholars' Journal*, 4, 1-13. <https://www.nepjol.info/index.php/scholars/article/view/42457>.
- Vu, Q., & Nga, N. T. T. (2022). Does the implementation of internal controls promote firm profitability? Evidence from private Vietnamese small-and medium-sized enterprises (SMEs). *Finance Research Letters*, 45, 102-178. <https://www.sciencedirect.com/science/article/abs/pii/S1544612321002506>.
- Vulley, D. (2022). Factors influencing the effectiveness of internal control systems: A case study of commercial banks in Ghana. *European Journal of Accounting, Auditing and Finance Research*, 10(4), 63-75. <https://www.eajournals.org/wp-content/uploads/Factors-Influencing-the-Effectiveness-of-Internal-Control-Systems.pdf>.
- Wali, S., & Masmoudi, S. M. (2020). Internal control and real earnings management in the French context. *Journal of Financial Reporting and Accounting*, 18(2), 363-387. <https://www.emerald.com/insight/content/doi/10.1108/JFRA-09-20190117/full/html>.
- Zucker, L. G. (1987). Institutional theories of organisation. *Annual Review of Sociology*, 13(1), 443-464. [https://edisciplinas.usp.br/pluginfile.php/7948425/mod\\_resource/content/3/ZUCKER%2C%20Lynne%20G.%20Institutional%20theories%20of%20organization.%20.pdf](https://edisciplinas.usp.br/pluginfile.php/7948425/mod_resource/content/3/ZUCKER%2C%20Lynne%20G.%20Institutional%20theories%20of%20organization.%20.pdf).

## THE IMPACT OF THE QUALITY OF SUSTAINABILITY REPORTING ON THE FINANCIAL PERFORMANCE OF LARGE COMPANIES OPERATING IN PORTUGAL

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Márcia Faria<sup>1</sup>, Sónia Monteiro<sup>2</sup>, Vanda Roque<sup>3</sup>

<sup>1</sup>Polytechnic University of Cávado and Ave (IPCA), School of Management, Portugal.

[a14981@alunos.ipca.pt](mailto:a14981@alunos.ipca.pt), ORCID: 0009-0004-3005-9887

<sup>2</sup>Polytechnic University of Cávado and Ave (IPCA), CICEF, School of Management, Portugal.

[smonteiro@ipca.pt](mailto:smonteiro@ipca.pt), ORCID: 0000-0003-2149-4962

<sup>3</sup>Polytechnic University of Cávado and Ave (IPCA), UNIAG, School of Management, Portugal.

[vroque@ipca.pt](mailto:vroque@ipca.pt), ORCID: 0000-0001-6038-1851

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### ABSTRACT

**Purpose-** The purpose of this paper is to investigate if the quality of sustainability reporting influences the financial performance of the largest Portuguese companies. Specifically, the paper aims to: i) evaluate the quality of sustainability reporting among Portuguese companies; ii) determine whether sustainability reporting quality impacts their financial performance.

**Methodology-** We evaluate sustainability reporting quality through content analysis of 2021 sustainability reports. Based on GRI Standards 502 disclosure requirements, we created a Sustainability Reporting Quality Index calculated as the ratio of disclosed items to total requirements. This global index is also divided into economic, environmental, and social sub-indices.

To analyze the impact of sustainability reporting quality on financial performance, we used a multiple linear regression model with ROE for 2022 as the dependent variable, and the sustainability index as independent variable. We also control for company size, revenue growth, and leverage.

**Findings:** The results indicate that Portuguese companies meet on average about 20% of GRI Standards disclosure requirements, indicating relatively low reporting quality. Among the sub-indices, companies disclose mainly information on economic performance, followed by social and environmental information. The findings also reveal that, although sustainability reporting quality has a positive effect on the financial performance of Portuguese companies, this impact is not statistically significant across all indices. Among the control variables, only revenue growth rate is statistically significant, exhibiting a positive relationship with financial performance.

**Conclusion:** This study investigates the impact of sustainability reporting quality on the financial performance of large Portuguese companies, using an innovative sustainability reporting index based on all GRI Standards disclosure requirements. The study finds that sustainability reporting quality in Portugal is generally low and has no significant impact of financial performance. A key limitation is the focus on the short term, which may miss potential long-term effects.

**Keywords:** Sustainability reports, GRI standards, financial performance

**JEL Codes:** M14, M41

## 1. INTRODUCTION

The growing market attention to sustainability-related business practices, along with investors' appreciation for greater transparency in this information, emphasizes the strategic importance of incorporating such elements into corporate management. By adopting this approach, companies can gain competitive advantages, as they demonstrate a solid commitment to sustainability and meet the demand of market increasingly sensible to corporate environmental and social responsibility.

While Bebbington et al. (2008) argue that the primary purpose of companies in disclosing sustainability reports is to obtain or preserve their reputation, Handoko and Lindawati (2020) highlight that sustainability reports enhance a company's reputation and image while also contributing valuable insights to strategic planning, organizational structure, and corporate responsibility. According to the authors, sustainability reports play a crucial role in global business practice, as they are relevant for assessing corporate social responsibility and demonstrating a commitment to sustainable development. Furthermore, the disclosure of sustainability reports can contribute to improving financial performance and the legitimacy of companies.

Despite the growth in sustainability reporting, there are few studies that focus on the quality of such reports (Minutiello & Tettamanzi, 2022), as well as there are few studies that investigate the impact of this disclosure on company financial performance. Moreover, existing studies mainly focus on publicly traded companies (e.g., Pulino et al., 2022; Carvajal & Nadeem, 2022; Reverte, 2016; Berthelot et al., 2012). On the other hand, the results of the studies conducted are not consistent. Some studies demonstrate that this type of disclosure increases companies' financial performance (Pulino et al., 2022; Carvajal & Nadeem, 2022; Reverte, 2016; Berthelot et al., 2012). Others argue that sustainable disclosures have a negative impact (e.g., Ece & Sari, 2020; Buallay, 2019) or a neutral impact (e.g., Ching et al., 2017) on business performance.

In light of the above, this paper aims to analyze the impact of the quality of sustainability reporting on the financial performance of Portuguese companies. The specific objectives are:

- Analyze the quality of sustainability reporting by Portuguese companies.
- Analyze if the quality of sustainability reporting affects the financial performance of Portuguese companies.

Given the increasing number of sustainability reports disclosed in Portugal and the lack of studies that investigate the impact of these disclosures on Portuguese companies' financial performance, this study offers an important contribution to the literature.

The paper is structured as follows. Section 2 is dedicated to the literature review on sustainability reporting. Section 3 presents the research design, including the research hypothesis, the sample and the methodology for data collection and analysis. Section 4 presents and discusses the results. Section 5 concludes with the main findings, limitations and suggestions for future research.

## **2. THEORETICAL BACKGROUND AND HYPOTHESIS DEVELOPMENT**

The growing importance of sustainability reporting is evident in the studies conducted by KPMG (2022), which highlight a continuous growth in the number of sustainability reports published by companies over the past two decades. The Global Reporting Initiative (GRI) standards are noted as the most adopted by companies in non-financial reports and is, therefore, considered as the most widely used international reference for sustainability reporting.

GRI launched the first guidelines in 2000, known as GRI G1. In 2002, they released GRI G2, outlining new disclosure guidelines. Four years later, GRI G3 was launched, which included communication formats, sectoral supplements, and indicators. In 2011 GRI G3 was replaced with a new version of standards, GRI G3.1 (Aifuwa, 2020), and in 2013 GRI G4 was released. As GRI guidelines began to be used worldwide, GRI G4 were replaced by GRI Standards in 2016 (from guidelines to standards). These standards have been constantly updated, considering the need for a more comprehensive disclosure of sustainable information.

In 2014, the Directive 2014/95/EU (transposed into Portuguese law by DL Nº 89/2017) on the disclosure of non-financial information came into force, requiring companies with more than 500 employees to disclose information on environmental issues, social aspects, human rights, anti-corruption, and anti-bribery efforts. Companies must include this information in their annual report or in a separate report.

Empirical evidence has shown that some companies choose to comply with this directive by publishing sustainability reports (Pereira et al., 2020; Balluchi et al., 2020; Loureiro et al., 2023), often following the GRI standards guidelines.

The GRI 2016 standards consist of three main parts:

- Universal standards, which include three subsections: foundation (GRI 101), which outlines essential guidelines for sustainability reporting; general disclosure (GRI 102), incorporating a brief company description; and management approach (GRI 103), which sets out requirements for reporting to organizations.
- Specific standards that provide detailed guidance on the information to be disclosed in sustainability reports. These standards are divided into three categories: economic dimension (GRI 200), environmental dimension (GRI 300), and social dimension (GRI 400). Economic standards require companies to reflect the organization's impact on stakeholders' economic conditions, as well as on local, national, and global economic systems. Environmental standards concern the impact of the company on land, air, water, and ecosystems during its normal activities. Finally, social dimension standards should describe the organization's impact on the social system in which it operates.
- Sectoral standards, that offer specific guidance for sustainability reporting in specific sectors such as banking, mining, energy, among others.

In Portugal, GRI Standards were the most widely used among publicly traded companies (Carmo & Ribeiro, 2022; Monteiro et al., 2023). Additionally, Carmo and Ribeiro (2022) concluded that companies using GRI Standards as guidance for sustainability reporting are more likely to provide more detailed information in their reports.

Since the 2000s, socially responsible investors have increasingly sought greater transparency and social and environmental information from companies, as evidenced by the growing demand for sustainability reports (Haigh, 2008).

In preparing sustainability reports, managers must consider that different stakeholder groups have distinct interests in the company. For example, while shareholders are interested in the return on their investment, employees focus on feeling safe at work and being well compensated. Taking this into account, reports should be as comprehensive as possible to include information that is relevant to all interested groups (Botchwey et al., 2022).

Thus, sustainability reporting is seen as an information tool to manage the information needs of different stakeholders (Reverte, 2016). Some authors consider that the focus on stakeholders is a viable approach to explain companies' environmental and social behavior. Socially and environmentally responsible activities and disclosures should be part of a strategic plan to manage stakeholder relationships and to develop a reputation as a socially and environmentally responsible organization (Roberts, 1992).

Stakeholder Theory is one of the dominant theories to explain organizations' voluntary disclosure of sustainability reports. This theory argues that companies have responsibilities to all groups interested in their business, not just their shareholders (Freeman, 1984). Thus, the information disclosed by entities targets not only investors and shareholders, as traditional theories suggest, but also a wide range of corporate information users. (Deegan et al., 2002). Furthermore, Stakeholder Theory suggests that a company engaging in activities beyond profit maximization will create value for itself and its stakeholders (Qureshi et al., 2020).

Although sustainability reporting is becoming more common, there is a paucity of research examining the impact of this disclosure on corporate financial performance. Existing studies mainly focus on listed companies (e.g., Berthelot et al., 2012; Carvajal & Nadeem, 2022; Pulino et al., 2022; Reverte, 2016; Swarnapali, 2018) or specific business sectors (Pulino et al., 2022).

Moreover, the results of existing studies are not consistent. Some studies demonstrate that sustainability information disclosure has a positive impact on companies' financial performance (e.g., Carvajal & Nadeem, 2022; Ermenc et al., 2017; Garg, 2015; Pulino et al., 2022; Reverte, 2016). Carvajal and Nadeem (2022) found that sustainability information disclosure is positively associated with company performance in New Zealand, supporting Stakeholder Theory. Garg (2015) argues that sustainability disclosure practices have a positive impact on companies' long-term financial performance. Pulino et al. (2022) analyzed the sustainability reports of Italian companies and concluded that sustainability reporting has a positive impact on financial performance. These authors found that when companies increase investment in environmental sustainability projects, their performance also increases. Ermenc et al. (2017) analyzed the sustainability information disclosure of non-financial companies in Slovenia and concluded that companies, by improving their sustainable performance, can improve their financial performance in the following three years.

On the other hand, other authors argue that sustainability information disclosure has a negative impact on financial performance (e.g., Buallay, 2019; Ece & Sari, 2020). Ece and Sari (2020) conclude that sustainability reporting has a negative relationship with organizations' financial performance, as assessed by return on equity (ROE) and return on assets (ROA). According to Ece and Sari (2020), the negative relationship is due to the costs associated with corporate social responsibility activities; many companies choose not to disclose sustainability information, believing that the cost of reporting outweighs the benefits in the short term (Al Hawaj & Buallay, 2022; Garg, 2015).

The quality of sustainability reports has received attention from several studies as reports with high quality can faithfully represent an organization's sustainable performance (Minutiello & Tettamanzi, 2022). A high-quality sustainability report is necessary to meet both internal (corporate governance) and external (stakeholders) information demands (Hidayah et al., 2021). However, according to Hoffmann et al. (2018), companies present reports with quite incomplete information, demonstrating the low quality of their non-financial reporting.

Bachoo et al. (2013) evaluates the quality of sustainability reports of Australian companies between 2003 and 2005 and conclude that the market values high-quality sustainability reports. Loh et al. (2017), considering a sample of companies listed in the Singapore exchange, also found that the higher the quality of the sustainability report, the higher the companies' market value. Similarly, Hongming et al. (2020) found that the quality of non-financial information is positively related to companies' financial performance.

On the other hand, Ching et al. (2017) point to a neutral relationship between the quality of sustainability reports and the financial performance of Brazilian companies. According to the authors, in equilibrium, the gains from the

company's social responsibility offset its costs. Ching et al. (2017) indicate that these results may be associated with the stakeholders' understanding of the commitment of the company to the environmental and social activities or companies may be undertaking expensive sustainability initiatives to reduce information asymmetries.

Considering the theoretical and empirical literature presented above, we define the following research hypothesis:

*H1 - Companies that present sustainability reports with higher quality tend to have superior financial performance.*

We believe that sustainability reporting aims to increase transparency about the economic, environmental, and social performance of a company. This transparency may contribute to enhancing corporate reputation, increase stakeholders' confidence, attract investors and capital, thus having a positive impact on the company's value. This hypothesis is consistent with the idea that transparency and social responsibility can generate trust and value for stakeholders, which may, in turn, contribute to companies' financial success. Additionally, we believe that the quality of sustainability reports is of paramount importance, as low-quality reports may not accurately reflect the company's sustainable performance and may fail to meet stakeholders' expectations.

### 3. RESEARCH DESIGN

#### 3.1. Sample

In this study we considered the list of the "500 Largest & Best Portuguese Companies", according to the special edition of Exame magazine for the year 2021. From these, we only consider companies that report non-financial information separately in sustainability reports, excluding companies that do not disclose sustainable information or that disclosed sustainable information through other types of reports (e.g., integrated report, financial statements). We also had to exclude three companies that did disclose sustainability reports but did not have financial data available for the year 2022 at the time of data collection. Thus, we are left with 63 companies in the sample.

#### 3.2. Methodology

To determine the quality of sustainability reporting, we conducted a content analysis of the 2021 sustainability reports published by the companies in our sample. For the analysis of the sustainability reports, we examined 502 disclosure requirements based on the GRI Standards 2016, specifically the disclosure requirements suggested by the GRI Content Standards, covering:

- The universal standards: general disclosures (GRI 102) and management approach (GRI 103), for each specific standard, in a total of 166 disclosure requirements.
- The specific standards: topics related to economic performance (GRI 200), environmental performance (GRI 300), and social performance (GRI 400), in a total of 336 disclosure requirements.

We developed a sustainability reporting quality index to measure the quality of information in the sustainability reports of Portuguese companies. For each requirement, a value of 1 was assigned if it was disclosed in the sustainability report, and a value of 0 otherwise. The final value of the index is the ratio of the total requirements disclosed by each company and the total sum of requirements that constitute the disclosure index, according to equation 1:

$$IND_j = \frac{\sum_{n=1}^i i_n}{i} \quad (1)$$

where:  $IND_j$  is the sustainability reporting quality index of company  $j$ ;  $i_n$  is the sustainability disclosure requirement  $i$  under analysis, a dummy variable that takes the value 1 if company  $j$  discloses the sustainability disclosure requirement  $i$ , 0 otherwise; and  $i$  is the total of sustainability disclosure requirement in the index.

Based on the GRI Standards 2016, the Quality Index was also divided into the following themes: Economic, Environmental, and Social, using the same calculation method used in the Sustainability Reporting Quality Index. That is, in the construction of the total sustainability reporting index, the entire set of 502 disclosure requirements under analysis was considered. In the construction of sub-indices, the maximum number of disclosure requirements in each category was considered: economic (59), environmental (146), and social (131).

To investigate the impact of sustainability reporting quality on companies' financial performance, we use a multiple linear regression. The dependent variable is the ROE for 2022, the independent variables is the sustainability reporting quality index, and the control variables include size (as measured by the natural logarithm of assets), revenue growth rate, and leverage. The regression is as equation 2:

$$ROE = \alpha_0 + \beta_1 INDEX + \beta_2 SIZE + \beta_3 LEV + \beta_4 GROWTH + e_i \quad (2)$$

where ROE is the return of equity in 2022; INDEX is the sustainability reporting quality index; SIZE is the natural logarithm of assets in 2021; LEV is the company' leverage, assessed by the ratio of liabilities to assets in 2021; GROWTH is the growth rate of revenues in 2021.

ROE for 2022, as well as assets, leverage, and revenue growth rate for 2021, were obtained from the SABI database. The data was gathered in Excel and then imported into SPSS for statistical analysis.

#### 4. RESULTS ANALYSIS AND DISCUSSION

Table 1 presents the descriptive statistics for the sustainability reporting quality index, when we consider all dimensions (INDEX\_Global), or only the economic dimension (INDEX\_Economic), the environmental dimension (INDEX\_Environmental) or the social dimension (INDEX\_Social).

**Table 1: Descriptive Statistics for the Sustainability Reporting Quality Index**

INDEX	Min	Max	Average	Std.Dev.
Global	0.017	0.368	0.191	0.099
Economic	0.000	0.254	0.120	0.082
Environmental	0.000	0.191	0.087	0.057
Social	0.000	0.282	0.110	0.078

The global sustainability reporting quality index ranges from 0.017 to 0.368, with a mean of 0.191 and a standard deviation of 0.099. These results indicate that the quality of sustainability reporting is quite low among Portuguese companies since, on average, only 20% of the disclosure requirements advocated by the 2016 GRI Sustainability Reporting Standards are fulfilled by Portuguese companies. This finding is consistent with the studies of Carmo and Ribeiro (2022) and Hoffmann et al. (2018), which found that companies continue to report non-financial information with significant gaps, indicating room for improvement, as suggested by Hoffmann et al. (2018). Comparing the different sub-indices, we find that, on average, Portuguese companies disclose more information related to economic performance (12%), followed by social (11%) and environmental (9%) performance. Table 2 presents the descriptive statistics for the other variables.

**Table 2: Descriptive Statistics for Other Variables**

Variable	Min	Max	Average	Std.Dev.
ROE	-219.883	614.824	39.803	92.135
SIZE	9.485	17.208	12.415	1.545
LEV	1.146	127.898	63.762	23.956
GROWTH	-99.098	145.768	12.812	28.691

The sample consists of large companies, with the natural logarithm of assets averaging 12,332. On average, corporations in the sample have a ROE close to 40%, with high variability within the sample, a leverage of 40% and a revenues' growth rate of 12.8%. Table 3 presents the correlation matrix.

**Table 3: Correlation Matrix**

	INDEX Global	INDEX Economic	INDEX Env.	INDEX Social	SIZE	LEVERAGE	GROWTH
INDEX_Global	1						
INDEX_Economic	0.750***	1					
INDEX_Environmental	0.649***	0.614***	1				
INDEX_Social	0.666***	0.802***	0.540***	1			
SIZE	0.141	0.117	0.266**	-0.019	1		
LEVERAGE	-0.001	-0.033	-0.183	0.027	-0.059	1	
GROWTH	0.129	0.177	0.240*	0.063	0.104	0.229*	1

There is a high correlation among the sustainability reporting quality indices (overall, economic, environmental, and social), which is expected and is not a problem since we only use one of the indices in each regression. The remaining Pearson correlation coefficients are below 0.30, suggesting the absence of multicollinearity issues.

Table 4 presents the results of the four multiple linear regressions conducted to investigate the impact of the quality of sustainability reporting on the financial performance of Portuguese companies. Each regression considers one of the sustainability reporting quality indexes (global, economic, environmental and social).

The results show that, regardless of the index considered, the quality of sustainability reporting has a positive, albeit not significant, impact on financial performance of Portuguese companies. The magnitude of this effect is higher for social disclosures, followed by economic disclosures and finally environmental disclosures.

Since the relationship between the quality of sustainability reporting and the financial performance of Portuguese companies, although a positive, is not statistically significant, our research hypothesis cannot be validated. Therefore, it is not possible to assert that the quality of sustainability reporting impacts the financial performance of Portuguese companies. This result contradicts the findings of Bachoo et al. (2013) and Hongming et al. (2020).

Regarding the control variables, only the revenue growth rate shows a statistically significant impact on financial performance. This relationship is positive, indicating that companies with higher revenue growth have higher ROE.

The four models are statistically significant and explain around 30% of the variability of financial performance. The VIF values obtained in each regression confirm the absence of multicollinearity.

**Table 4: Impact of the Quality of Sustainability Reporting on the Financial Performance**

	Global		Economic		Environmental		Social	
	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat
Constant	63.947	0.908	63.742	0.908	70.439	0.998	56.479	0.796
INDEX	79.91	0.993	112.346	1.140	62.234	0.426	119.471	1.180
SIZE	-6.998	-1.319	-6.896	-1.308	-6.875	-1.261	-6.175	-1.178
LEV	0.333	0.979	0.353	1.038	0.362	1.026	0.322	0.950
GROWTH	1.253	4.369***	1.228	4.280***	1.252	4.223***	1.266	4.480***
N	63		63		63		63	
Z	6.660***		6.773***		6.372***		6.806***	
R <sup>2</sup>	0.315		0.318		0.305		0.319	
R <sub>α</sub> <sup>2</sup>	0.268		0.271		0.257		0.273	
Mean VIF	1.055		1.063		1.141		1.041	

## 5. CONCLUSION

This study contributes to the literature by providing additional empirical evidence on the quality of sustainability reporting and its impact on the financial performance of large Portuguese companies. To the best of our knowledge, previous studies on the quality of sustainability reporting did not comprehensively consider all disclosure requirements specified in the GRI Standards, making our sustainability reporting index an innovative analytical tool that allows for a thorough evaluation of compliance with the GRI Framework.

Due to the detail of the indices, it was found that the average quality of sustainability reports published by Portuguese companies is quite low (about 20%). These results indicate that many of the disclosure requirements outlined in the GRI Standards 2016 are not being met.

The results show that, although there is a positive relationship between the quality of sustainability reporting and financial performance, this relationship is not statistically significant, leading to the conclusion that financial performance is not influenced by the quality of sustainability reporting. These findings contradict those obtained by Bachoo et al. (2013) and Hongming et al. (2020). Indeed, despite the lack of consensus among various studies, previous studies have suggested a relationship between both variables. However, this study demonstrates that there is no significant relationship between the quality of reporting and financial performance of Portuguese companies.

Our study has some limitations. First, the sample only considers companies reporting non-financial information separately in sustainability reports. However, many Portuguese companies include sustainability information disclosure in their financial statements and/or in integrated reports. Therefore, if these reports were included in the sample, the results might have been different. Thus, for future studies, it is recommended to also analyze the content of sustainability information in financial statements and integrated reports.

Second, we analyzed the impact of the quality of reports published in 2021 on the financial performance of 2022, i.e., we only examined the effect in the subsequent year. Therefore, it was not possible to observe the long-term effect of sustainability information disclosures. Some studies (e.g., Ermenc et al., 2017; Garg, 2015) conclude that companies that adopt sustainable reporting practices typically see improvements in financial performance only in the long term. Thus, sustainability reporting often lacks immediate financial impact, and companies may need to wait several years for sustainability disclosures to generate returns and positively affect financial performance. As a suggestion for

future studies, we propose a more extensive longitudinal study. This type of study allows for a larger number of observations, enabling the analysis of the evolution of sustainability reporting practices and their temporal effect on financial performance. An approach to sustainability reporting over the long term would assess whether financial benefits gradually materialize as sustainable practices are integrated into corporate strategy and are consistently communicated over time.

Third, the low value of the sustainability reporting quality index obtained in our study may be due to the quantity and detail of disclosure requirements. This may contribute to encouraging a discussion among regulatory bodies (such as GRI itself) on the balance between the quantity and detail of disclosure requirements and the quality of information disclosed by companies.

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### **REFERENCES**

- Aifuwa, H. O. (2020). Sustainability Reporting and firm performance in developing climes: A review of literature. *Copernican Journal of Finance & Accounting*, 9(1), 9-29.
- Al Hawaj, A. Y., & Buallay, A. M. (2022). A worldwide sectorial analysis of sustainability reporting and its impact on firm performance. *Journal of Sustainable Finance & Investment*, 12(1), 62–86.
- Bachoo, K., Tan, R., & Wilson, M. (2013). Firm Value and the Quality of Sustainability Reporting in Australia: Firm Value and the Quality of Sustainability Reporting. *Australian Accounting Review*, 23(1), 67–87.
- Balluchi, F., Lazzini, A. & Torelli, R. (2020). Credibility of environmental issues in non-financial mandatory disclosure: measurement and determinants. *Journal of Cleaner Production*, 288, 125744.
- Bebbington, J., Larrinaga, C., & Moneva, J. M. (2008). Corporate social reporting and reputation risk management. *Accounting, Auditing & Accountability Journal*, 21(3), 337-361.
- Berthelot, S., Coulmont, M., & Serret, V. (2012). Do Investors Value Sustainability Reports? A Canadian Study: Do Investors Value Sustainability Reports? A Canadian Study. *Corporate Social Responsibility and Environmental Management*, 19(6), 355–363.
- Botchwey, E. A., Soku, M. G., & Awadzie, D. M. (2022). Sustainability reporting and the financial performance of banks in Africa. *Journal of Business, Economics and Finance*, 11 (1),43-57.
- Buallay, A. (2019). Between cost and value: Investigating the effects of sustainability reporting on a firm's performance. *Journal of Applied Accounting Research*, 20(4), 481–496.
- Carmo, C., & Ribeiro, C. (2022). Mandatory Non-Financial Information Disclosure under European Directive 95/2014/EU: Evidence from Portuguese Listed Companies. *Sustainability*, 14(8), 4860.
- Carvajal, M., & Nadeem, M. (2022). Financially material sustainability reporting and firm performance in New Zealand. *Meditari Accountancy Research*. 31(4), 938-969.
- Ching, H. Y., Gerab, F., & Toste, T. H. (2017). The Quality of Sustainability Reports and Corporate Financial Performance: Evidence from Brazilian Listed Companies. *SAGE Open*, April-june, 7(2), 1-9.
- Deegan, C., Rankin, M. & Tobin, J. (2002), An examination of the corporate social and environmental disclosures of BHP from 1983-1997: A test of legitimacy theory, *Accounting, Auditing & Accountability Journal*, 15 (3), 312-343.
- Ece, O., & Sari, S. S. (2020). Relationship between corporate sustainability reporting and firm efficiency, productivity, and profitability and firm value: Evidence from Turkey. *Academic Studies in Economics and Administrative Sciences*, 83-113.
- Ermenc, A., Klemenčič, M., & Rejc Buhovac, A. (2017). Sustainability Reporting in Slovenia: Does Sustainability Reporting Impact Financial Performance? Em P. Horváth & J. M. Pütter (Eds.), *Sustainability Reporting in Central and Eastern European Companies* (pp. 181–197). Springer International Publishing.
- Freeman, R. E. (1984). *Strategic Management: A Stakeholder Perspective*. Pitman, 1984.
- Garg, P. (2015). Impact of Sustainability Reporting on Firm Performance of Companies in India. *International Journal of Marketing and Business Communication*, 4(3). 33-45.
- Haigh, M. (2008). What counts in social investment: evidence from an international survey. *Advances in Public Interest Accounting Journal*, 13, 35-62.
- Handoko, B., & Lindawati, A. (2020). The Importance of Sustainability Audit Report in Go Public Companies Sector, in Indonesia. *Advances in Science, Technology and Engineering Systems Journal*, 5(4), 217-222.
- Hidayah, N., Nugroho, L., & Prihanto, H. (2021). The determinant factors of sustainability report quality and corporate performance: An empirical study. *International Journal of Finance, Insurance and Risk Management*, 11(1), 24-37.

- Hoffmann, E., Dietsche, C., & Hobelsberger, C. (2018). Between mandatory and voluntary: Non-financial reporting by German companies. *Sustainability Management Forum*, 26 (1–4), 47–63.
- Hongming, X., Ahmed, B., Hussain, A., Rehman, A., Ullah, I., & Khan, F. U. (2020). Sustainability Reporting and Firm Performance: The Demonstration of Pakistani Firms. *SAGE Open*, 10(3), 215824402095318.
- KPMG. (2022). Big shifts, small steps: Survey of Sustainability Reporting 2022.
- Loh, L., Thomas, T., & Wang, Y. (2017). Sustainability Reporting and Firm Value: Evidence from Singapore-Listed Companies. *Sustainability*, 9(11), 2112.
- Loureiro, A.; Monteiro, S. & Ribeiro, V. (2023). Exploring the SDGs in the Non-Financial Reporting Practices by the Largest Portuguese Companies: A Longitudinal Analysis Since the 2030 Agenda Approval, Chapter book, IGI Global “Enhancing Sustainability Through Non-Financial Reporting”, pp. 1-19, ISBN13: 9781668490761.
- Minutiello, V., & Tettamanzi, P. (2022). The quality of nonfinancial voluntary disclosure: A systematic literature network analysis on sustainability reporting and integrated reporting. *Corporate Social Responsibility and Environmental Management*, 29(1), 1–18.
- Monteiro, S., Marques, R., Lemos, K. (2023). Fatores determinantes do relato não financeiro obrigatório vs voluntário em grandes empresas portuguesas. *International Workshop on Accounting and Taxation - IWAT2023*, Oporto, 17 February.
- Pereira, L., Lemos, K.; Monteiro, S., Ribeiro; V. (2020). The Determinants of Non-Financial Reporting in Portuguese Listed Companies, Proceedings of the 35th International Business Information Management Association Conference (IBIMA) - Education Excellence and Innovation Management: A 2025 Vision to Sustain Economic Development during Global Challenges, 1-2 April 2020 Seville, Spain, ISBN: 978-0-9998551-4-1
- Pulino, S., Ciaburri, M., Magnanelli, B. S., & Nasta, L. (2022). Does ESG Disclosure Influence Firm Performance? *Sustainability*, 14(13), 7595.
- Qureshi, M. A., Kirkerud, S., Theresa, K., & Ahsan, T. (2020). The impact of sustainability (environmental, social, and governance) disclosure and board diversity on firm value: The moderating role of industry sensitivity. *Business Strategy and the Environment*, 29(3), 1199–1214.
- Reverte, C. (2016). Corporate social responsibility disclosure and market valuation: Evidence from Spanish listed firms. *Review of Managerial Science*, 10(2), 411–435.
- Roberts, R. (1992). Determinants of corporate social responsibility disclosure: an application of Stakeholder Theory. *Accounting, Organizations and Society*, 17 (6), 595-612.
- Swarnapali, R. (2018). Corporate sustainability reporting and firm value: Evidence from a developing country. *International Journal of Organizational Innovation*, 10(4), 69- 78.

## TIME-VARYING CONNECTEDNESS BETWEEN GREEN MARKETS AND CABLE NEWS-BASED ECONOMIC POLICY UNCERTAINTY: EVIDENCE FROM A TVP-VAR CONNECTEDNESS APPROACH

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**Selim Gungor**

Tokat Gaziosmanpasa University, Resadiye Vocational School, Department of Management and Organization, Tokat, Turkiye.

[selim.gungor@gop.edu.tr](mailto:selim.gungor@gop.edu.tr), ORCID: 0000-0002-2997-1113

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### ABSTRACT

**Purpose-** Governments and businesses worldwide are actively driving the growth of green finance (GF) markets as part of their goals towards a natural, sustainable, zero-carbon economy. Along with the turbulent events and developments in global markets, economic policy uncertainty (EPU) levels are constantly increasing, leading to significant spillover shocks on various economic and financial factors. Accordingly, this research aims to identify the dynamic connectivity between cable news-based EPU (TVEPU) and green asset returns, considering the period between 01.10.2014 and 30.09.2024.

**Methodology-** This research employs the TVP-VAR connectedness method to examine the nexus between TVEPU and the returns of green assets. This approach enables the estimation of a generalized connectedness procedure using variance-covariance matrices and time-varying coefficients. Additionally, by applying Wold's representation theorem, it calculates generalized impulse response functions (GIRF) and variance decompositions (GFEVD) to predict the connectedness indices between the variables.

**Findings-** First, we observe that the Fossil Fuel Reserves Free index has the highest influence on other indices while the TVEPU index has the lowest impact on other indices. Second, we find that shocks from international events and news significantly increase the sensitivity of the spillover effects between green assets and TVEPU. Third, we demonstrate that the Green Bond (GB) market is a net shock receiver; simultaneously, the Fossil Fuel Reserves Free, Sustainability World and Environmental and Social Responsibility indices are net shock transmitters. Moreover, the findings demonstrate that the net spillover of TVEPU, Global Clean Energy, Carbon Emission Allowances (CEAs) and Renewable Energy and Clean Technology indices changes over time. Fourth, we determine that TVEPU has a meagre impact on the returns of green stocks (GSs) and GBs.

**Conclusion-** This research provides strong evidence that news from wired news networks also impacts uncertainty shocks, emphasising that green asset investors should determine their portfolio diversification and hedging strategies by considering this factor.

**Keywords:** TVEPU, green financial markets, sustainable assets, dynamic connectedness, TVP-VAR based connectedness technique.

**JEL Codes:** D53, E60, Q56.

### 1. INTRODUCTION

Since the early 2000s, the international community has consistently accepted the critical need to address climate challenges and transition to a zero-carbon economy. Key frameworks like the Paris Agreement established in 2015 emphasise limiting global heat spikes, enhancing climate resilience and advancing sustainable progress. At the same time, the growth of the environmental movement has drawn significant attention to green markets, which aim to achieve carbon neutrality and support sustainability initiatives (McCollum et al., 2018; Iacobuță et al., 2022).

Early efforts by the international financial sector to align financial power with ecological benefits were adapted to address global climate challenges. This event led to the development of GF as an economic factor. GF markets facilitate funding green energy initiatives by offering financial services and operational capital. Within this framework, GBs, called climate bonds, are stable-income instruments primarily used to support environmental conservation and climate change projects. Banks play an essential role in enabling companies and governments to provide financing for projects with favourable ecological outcomes. Additionally, GSs are often associated with businesses that focus on renewable and alternative energy, waste reduction, sustainable transport, recycling, aquaculture, pollution control and organic farming. On the macro side, this situation is grounded in the collective rationality that corresponds to the attempts of World states to eliminate climate risks (Kazlauskienė et al., 2017; Berrou et al., 2019).

GF serves as both a crucial enabler and a fundamental prerequisite for sustainable development programs, supporting green technologies and fostering environmental accountability. Simultaneously, the growth of green markets reflects a collective commitment to building an eco-friendly society and mitigating global warming. At the micro level, this approach is grounded in individual rationality, aligning with companies' voluntary actions to preserve the environment (Braouezec and Joliet, 2019; Madaleno et al., 2022).

Over the past 25 years, the rapid succession of international events has heightened global economic uncertainty, prompting nations to examine its effects on the broader economy and asset markets. This growing concern has driven EPU to unprecedented levels worldwide, influencing asset markets directly and indirectly. Elevated uncertainty impacts firms' operations and profitability through the direct channel, resulting in asset price volatility. Indirectly, uncertainty increases investors' concerns about future economic growth, leading to a significant fall in stabilised asset values (Bansal and Shaliastovich, 2010; Luo and Zhang, 2020). However, green assets are also vulnerable to the influence of the EPU. This condition discourages buying behaviour in the green asset market because the increase in EPU will likely deteriorate expectations and hamper the forecasting ability of financial institutions and investors. Investors also face more significant valuation uncertainty, information costs and information asymmetry when uncertainty is high.

Against the continuous and increasing EPU background, lenders and stakeholders are becoming more conservative and applying tighter issuance criteria for green assets, thus limiting the availability of financing for projects. However, green asset markets offer a hedge against EPU by attracting long-term investors who prioritize sustainable development and are less likely to make impulsive decisions during market fluctuations (Nagar et al., 2019; Wei et al., 2021). Consequently, identifying instruments to ensure coherence and balance between green asset markets and EPU remains a critical frontier. Therefore, this paper explores the dynamic interconnectedness between TVEPU and green asset returns.

This research makes two substantial contributions to the existing literature. First, since EPU is not directly observable, previous studies have constructed it in various ways: by analyzing political and economic events (Hong and Kostovetsky, 2012), mining uncertainty using macroeconomic indicators and financial market data, constructing it from news reports on reputable platforms (Baker et al., 2016), and developing EPU using artificial intelligence from large US cable news networks such as Fox News, MSNBC and CNN (Hong et al., 2021; Bergbrant and Bradley, 2022). The Pew Research Centre reported that the primary source of American political information is about 3% newspaper-based sources and about 16% cable news. This observation is an imperative factor that triggers uncertainty (Bergbrant and Bradley, 2022). Furthermore, the growing level of factors such as the COVID-19 pandemic, FED interest rate hikes, trade policy war with China, Russia-Ukraine and Israel-Palestine wars, and the collapse of Silicon Valley Bank, which are driving US uncertainty indices from cable news networks, is highly likely that such factors will affect the green asset market. Secondly, Campbell and Shiller (1991) argued that the time-varying market price of risks and available information on financial asset returns have predictive power for future financial asset returns. Therefore, this paper utilises factors that enhance forecasting power by providing an experimental testbed for the influence of systematic uncertainty on green asset returns with the help of a TVP-VAR connectedness model.

The other sections of this paper are organised as follows: Section 2 summarizes the existing literature on the topic, followed by Section 3, which outlines the research methods. Section 4 reports and analyses the empirical results, and finally, Section 5 offers a theoretical interpretation of the policy implications and results.

## **2. LITERATURE REVIEW**

As environmental challenges continue to grow, researchers have shown increasing interest in green financial markets. Theoretically, EPU can lead to both upside and downside movements in the prices and yields of green assets, affecting investors' perceptions of a company's growth potential and possibly reducing their desire to engage in the green market (Pástor and Veronesi, 2013). As a result, the association between green markets and EPU has been extensively analysed in the literature, often using indicators derived from newspapers or cable news.

Pham and Nguyen (2022) examined the sensitivity of the GB market to US EPU using TVP-VAR and Markov regime-switching models. Their results indicated that GBs protect against uncertainty during periods of low uncertainty, but their hedging effectiveness decreases when uncertainty is high. Syed et al. (2022), employing NARDL models, investigated the asymmetric nexus between US EPU, global GBs, and the green energy index. They found that a positive shock in EPU negatively affects GBs, whereas a negative shock enhances their performance.

Wei et al. (2022) employed wavelet-based and multiscale quantile analyses to examine the link between EPU and the GB markets. Their results suggested a non-linear and time-varying causality from EPU to the GB market. Using quantile causality analysis, Lin and Su (2023) investigated the tail dependence of GB markets in the US and China with EPU and financial uncertainty. They concluded that financial uncertainty affects the US GB market more significantly, while EPU influences the Chinese market.

Finally, Wang et al. (2023) used quantile ARDL models to estimate the influence of China's EPU on the GB market. Their results showed that EPU has a negative and significant long-run effect on the GB market in most quantiles, whereas the short-run effects are positive and significant only in high quantiles.

Several studies in the literature investigate the impact of EPU on both GB and GS markets. Haq et al. (2021) employed DCC-MGARCH models to examine the dynamic relationship between EPU, GBs, and clean energy stocks, finding that GBs provide protection against EPU, while clean energy stocks and rare earths exhibit safe-haven characteristics. Urom et al. (2022) applied wavelets, cross-quantilogram techniques, and TVP-VAR models to explore sector-specific responses of clean investments to EPU, revealing that these responses vary by sector, market conditions, and time horizons.

Wang et al. (2022) applied time-varying causality analysis to explore the interaction between green market returns and EPU, finding a bidirectional and time-varying causality, with green markets serving as risk transmitters. Su et al. (2023) examined the relationship between GB and GS markets in China, using cross-quantilogram methods. They concluded that EPU does not significantly influence the interrelationships between these assets. Using quantile-quantile regression, Xi et al. (2023) discovered that EPU negatively impacts green financial markets, with GSs showing stronger reactions than GBs. Xia et al. (2023) used asymmetric TVP-VAR and EGARCH models to show that GBs, CEAs, and GSs serve as hedges against EPU, even when alternative EPU measures are applied. Adetokunbo and Mevhare (2024), using a TVP-VAR framework, highlighted that global EPU, linked to Brent oil prices, has a more pronounced volatility effect on green stocks, with the US EPU serving as a net volatility transmitter. Adebayo et al. (2024) employed wavelet quantile causality to demonstrate that time, frequency, and quantile significantly influence financial asset returns, including clean energy stocks and GBs.

Aloui et al. (2024) investigated the potential of clean energy stocks and GBs as safe havens in the face of global uncertainties using quintile wavelet models. Their findings revealed that the safe-haven activities of these assets fluctuate in terms of time horizons and risk conditions. Wang et al. (2024) explored the nexus between GBs, GSs, and EPU in China, employing nonparametric quantile methods. They discovered that the adverse predictive effects of EPU are more significant in extreme quantiles.

The existing literature underlines that the influence of EPU on green assets is usually measured by the EPU indicator introduced by Baker et al. (2016), whereas the number of papers utilising TVEPU is entirely restricted (Adebayo et al., 2024). Therefore, this paper is projected to contribute to filling a critical research gap in the literature.

### 3. DATA AND METHODOLOGY

This research intends to determine the time-varying connectivity between TVEPU and green asset returns for 01.10.2014-30.09.2024. The TVEPU index is an AI-based index developed by Hong et al. (2021) and Bergbrant and Bradley (2022) to construct EPU from major US cable news networks. In addition, following the existing literature (Syed et al., 2022; Wang et al., 2022; Adebayo et al., 2024; Aloui et al., 2024), this research considers GB and GS market indices to represent green assets. Meanwhile, the series of changes in TVEPU are obtained from the formula  $TVEPUC_t = \ln(Y_t) - \ln(Y_{t-1})$ , and the green asset returns are estimated by the formula  $r_t = \ln(p_t) - \ln(p_{t-1})$ . Table 1 provides detailed information about the data set. Table 2 contains descriptive statistics and stationarity results for the data.

**Table 1: Data set Informations**

Variables	Description	Data Sources
<b>Green Assets</b>		
<b>Green Stock Markets</b>		
SPXESRP	S&P 500 Environmental and Socially Responsible Index	www.spglobal.com
SPGSCEE	S&P GSCI Carbon Emission Allowances Index	
TXCT	S&P/TSX Renewable Energy and Clean Technology Index	
W1SGI	Dow Jones Sustainability World Index	
SP5F3UP	S&P 500 Fossil Fuel Reserves Free Index	
SPGTCEd	S&P Global Clean Energy Index	
<b>Green Bond Market</b>		
SPGBI	S&P Green Bond Index	www.spglobal.com
RTVEPU	Cable News-based Economic Policy Uncertainty Index	www.policyuncertainty.com

According to Table 2, excluding SPGBI and TXCT, the sample mean of all other variables is positive and very close to zero. However, there is a significant difference between the minimum and maximum values of the dependent and independent indicators, showing potential fluctuation levels. Standard deviation values state that the volatility of the RTVEPU variable is higher than the volatility of other indicators. The positive skewness values of the RTVEPU variable suggest that the variable

shows positive asymmetry and exhibits a right-skewed distribution. The negative skewness values of all other variables demonstrate that they are characterised by negative asymmetry and a left-skewed distribution. The kurtosis coefficients state that the distribution curves of all variables are characterised by leptokurtic to a large extent, and this pressure is more intense in all variables except SPGBI and SPGSCEE variables. In addition, according to Jarque-Bera statistics, the p-probability values of all variables are 0.0000, confirming that the indicators are not normally distributed. Ljung Box Q and Q<sup>2</sup> and ARCH statistics reveal a serious autocorrelation problem and autoregressive conditional heteroscedasticity effect at lag 20. Lastly, the significance level of ADF test statistics means that all variables are stationary. The time series graphs in Figure 1 also suggest that the variables do not exhibit a normal distribution and suffer from autocorrelation problems. The time series in Figure 1 also suggests that the indicators suffer from autocorrelation problems and are not normally distributed.

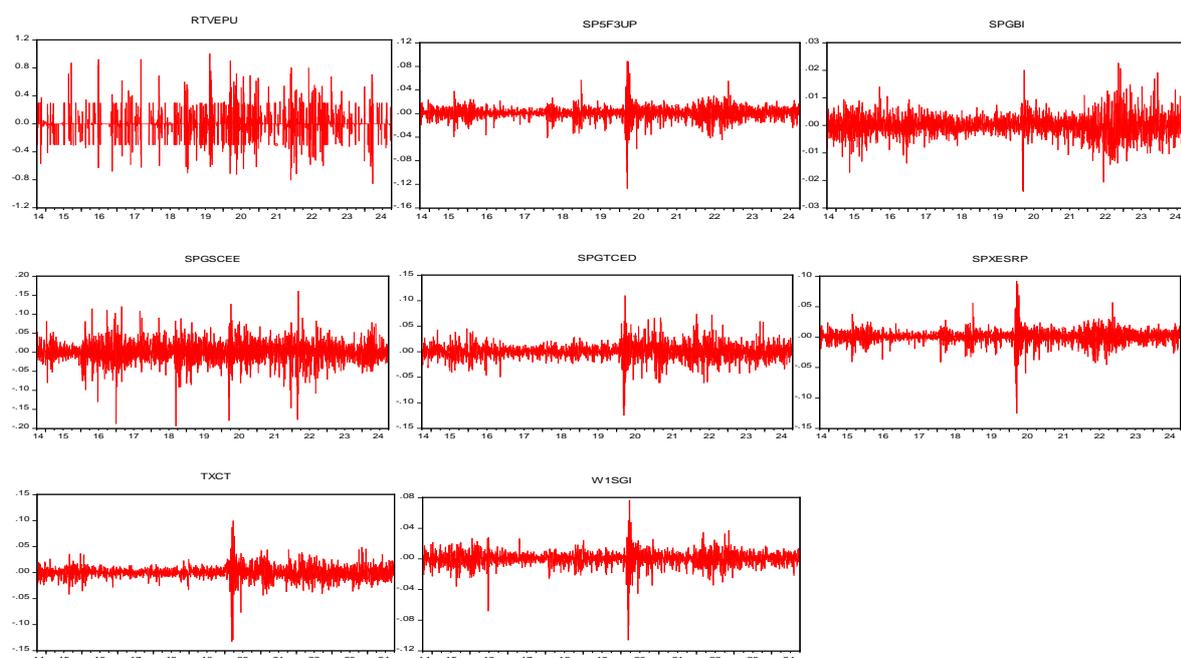
**Table 2: Descriptive and Unit Root Statistics**

	RTVEPU	SP5F3UP	SPGBI	SPGSCEE	SPGTCED	SPXESRP	TXCT	W1SGI
<b>Mean</b>	0.002951	0.000456	-8.15E-06	0.001018	0.000125	0.000457	-1.22E-05	0.000276
<b>Median</b>	0.000000	0.000572	6.73E-05	0.001344	0.000281	0.000557	0.000195	0.000620
<b>Max.</b>	1.007108	0.089156	0.022717	0.161353	0.110330	0.092403	0.099901	0.076939
<b>Min.</b>	-0.857617	-0.127369	-0.024099	-0.194283	-0.124971	-0.125476	-0.132895	-0.106051
<b>Std. Dev.</b>	0.165187	0.011392	0.003910	0.028634	0.015486	0.011508	0.013018	0.009314
<b>Skewness</b>	0.451526	-0.751778	-0.124729	-0.437145	-0.292673	-0.689355	-0.800649	-1.114701
<b>Kurtosis</b>	10.46194	18.12700	6.834301	7.558726	10.23389	17.41543	17.79518	18.66001
<b>Jarque-Bera</b>	5800.259*** 315.414***	23724.90*** 323.544***	1515.781*** 53.2359***	2212.094*** 29.8782***	5407.637*** 121.008***	21529.77*** 325.384***	22736.73*** 95.9860***	25687.82*** 161.671***
<b>Q(20)</b>	[0.0000] 667.709***	[0.0000] 3571.33***	[0.0000] 761.818***	[0.0071] 327.844***	[0.0000] 1870.18***	[0.0000] 3672.71***	[0.0000] 3887.83***	[0.0000] 2057.01***
<b>Q<sup>2</sup>(20)</b>	[0.0000] 22.688***	[0.0000] 80.288***	[0.0000] 16.024***	[0.0000] 8.7717***	[0.0000] 37.697***	[0.0000] 80.264***	[0.0000] 98.017***	[0.0000] 49.679***
<b>ARCH(20)</b>	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
<b>ADF</b>	-37.36071***	-15.87911***	-44.23193***	-51.81583***	-17.15008***	-15.83130***	-17.74388***	-16.12591***

Note: \*\*\* demonstrates statistical significance at the 1% level.

Additionally, Figure 1 shows that small changes follow small changes in variables. Similarly, large changes follow large changes. This fact indicates that volatility clustering is experienced in all variables.

**Figure 1: Time Series Graphs of Indicators for the Period 01.10.2014-30.09.2024**



This research utilises the TVP-VAR connectedness approach to investigate the time-varying dependence structure between TVEPU and green assets. The TVP-VAR provides more flexibility and robustness compared to conventional VAR models. The lower triangular matrix assumption performs the iterative identification task for the VAR system. Since many parameters are estimated in the TVP-VAR, researchers propose to reduce the number of parameters by assuming a random walk process for parameter innovation. Furthermore, this model shows that the extension of the forecasting algorithm to include a stationary process can be easily achieved (Nakajima, 2011). A classical TVP-VAR procedure can be constructed as in equation (1):

$$y_t = B_{1t}y_{t-1} + \dots + B_{kt}y_{t-k} + u_t, \quad u_t \sim N\left(0, A_t^{-1} \sum_t \varepsilon_t\right), t = 1, \dots, T \quad (1)$$

where  $y_t$  indicates  $nx1$  vector of variables.  $B_{it}, i = 1, \dots, k$  shows  $nxn$  time-varying coefficient matrices. Moreover,  $u_t$  represents  $nx1$  vector of structural shocks which have a lower triangular matrix  $A_t$  and diagonal matrix  $\sum_t. \varepsilon_t \sim N(0,1)$ .

The TVP-VAR connectedness technique builds upon the spillover index derived by Diebold and Yilmaz (2014). They used this method to estimate the generalized association procedure from variance-covariance matrices and time-varying coefficients. This approach calculates GIRF and GFEVD considering the method of Koop et al. (1996). It also converts the TVP-VAR procedure to a vector moving average (VMA) representation using the Wold representation theorem to calculate GIRF and GFEVD. The process of obtaining the VMA reproduction involves recursive displacement. The VMA reproduction is displayed as  $\sum_{j=0}^{\infty} A_{jt} \varepsilon_{t-j}$ ,  $A_{jt}$  is the  $nxn$  matrix. Assuming that  $|\beta_{(z)}|$  is outside the unit circle, the  $MA(\infty)$  process as  $y_t = \Psi(L)\varepsilon_t$ , traditionally depicts the VAR process, representing a fundamental aspect of time-varying relationship modelling in empirical macroeconomics. Where,  $\Psi(L)$  refers to a matrix of polynomials with infinite lags (Koop and Korobilis, 2013). In such a system, the relationships between variables are usually stated employing estimation error variance decomposition because shocks in one variable may affect others as well as itself. Since these shocks may not occur independently, the standard Cholesky decomposition based on ranking the variables according to the expected propagation of the shocks may not be appropriate. Therefore, we utilise the GFEVD methodology proposed by Koop and Korobilis (2014) to assess the pairwise link from variable (j) to variable (i). This approach effectively recognises the influence of indicator (j) on indicator (i) concerning the estimation variance margin. GFEVD can be expressed as follows:

$$\Gamma_{ij,t}(K) = \frac{\sum_{k=1}^{K-1} \omega_{ij,t}^2}{\sum_{j=1}^n \sum_{k=1}^{K-1} \omega_{ij,t}^2} \quad (2)$$

$\sum_{j=1}^n \Gamma_{ij,t}(K) = 1$  and  $\sum_{i=1}^n \Gamma_{ij,t}(K) = n$ .  $H$  is the number of forecast horizons.  $GIRF(\Psi_{ij,t}(K))$  can be calculated as follows:

$$GIRF_t(H, p_{j,t}, \Omega_{t-1}) = E(y_t + H|e_j = p_{j,t}, \Omega_{t-1}) - E(y_{t+j}|\Omega_{t-1}) \quad (3)$$

$$\Psi_{ij}(K) = \frac{A_{H,t} \sum_t e_j}{\sqrt{\sum_{j,t}} \sqrt{\sum_{j,t}}} p_{j,t} = \sqrt{\sum_{j,t}} \quad (4)$$

$$\Psi_{ij}(K) = \sum_{j,t}^{-1/2} A_{H,t} \sum_t e_j \quad (5)$$

$e_j$  shows an  $nx1$  vector, whose  $j$ th element equals 1.

One of the primary conditions for understanding financial markets is to analyse networks. The Total Connectedness Index (TCI) captures how a shock in one variable measures the transmission effect of a shock to others. According to Monte Carlo simulations, the individual variance shares are always more outstanding than or equal to the cross variance shares. This case limits the TCI to be in the range of  $\left[0, \frac{k-1}{k}\right]$ . In order to determine the average level of co-movement between networks as a percentage, the TCI needs to be adjusted slightly. TCI can be calculated as follows (Broadstock et al., 2022):

$$TCI_t^g(K) = \frac{\sum_{i,j=1, i \neq j}^m \vartheta_{ij,t}^g(K)}{k-1}, \quad 0 \leq TCI_t^g(K) \leq 1 \quad (6)$$

To compute the pairwise connectivity index (PCI) between assets  $i$  and  $j$ , the TCI index can be constructed as follows:

$$PCI_{ijt}(K) = 2 \left( \frac{\vartheta_{ij,t}^g(K) + \vartheta_{ji,t}^g(K)}{\vartheta_{ii,t}^g(K) + \vartheta_{jj,t}^g(K) + \vartheta_{ji,t}^g(K) + \vartheta_{ij,t}^g(K)} \right), \quad 0 \leq PCI_{ijt}^g(K) \leq 1 \quad (7)$$

Total directional connectivity index (TDCI) from others can be calculated as follows:

$$\Gamma_{i \leftarrow j,t}(K) = \frac{\sum_{j=1, i \neq j}^m \vartheta_{ij,t}(K)}{\sum_{i=1}^m \vartheta_{ij,t}(K)} * 100 \quad (8)$$

As the impact of indicator  $i$  on itself is eliminated, the TDCI of all other variables on variable  $i$  must be strictly less than 100 per cent. Considering GFEVD, TDCI to others is measured as follows:

$$\Gamma_{i \rightarrow j,t}(K) = \frac{\sum_{j=1, i \neq j}^n \vartheta_{j,i,t}(K)}{\sum_{j=1}^n \vartheta_{j,i,t}(K)} * 100 \quad (9)$$

This measure computes the effect of indicator  $i$  on all other indicators  $j$  in the system by summing the influence of indicator  $i$  on the forecast error variance of each of the other indicators. It is also beneficial to acknowledge that measures of TDCI can take values below, equal to or above 100 per cent. Net total directional connectivity index (NTDCI) describes the comprehensive impact of a variable  $i$  on the entire network. This measure considers the cumulative effect of the prediction error variance of indicator  $i$  on each of the other indicators in the system. It provides valuable insight into the overall importance of the indicator in the network. NTDCI is computed as follows:

$$\Gamma_{i,t} = \Gamma_{i \rightarrow j,t}(K) - \Gamma_{i \leftarrow j,t}(K) \quad (10)$$

If  $\Gamma_{i,t} > 0$ , variable  $i$  has a significant impact on the network. Conversely, if  $\Gamma_{i,t} < 0$ , variable  $i$  is being effected by the network. Net pairwise directional connectivity index (NPDCI) is a powerful instrument for examining the bidirectional nexus between indicator  $i$  and indicator  $j$ :

$$NPDCI_{ij}(K) = (\vartheta_{j,i,t}(K) - \vartheta_{i,j,t}(K)) * 100 \quad (11)$$

NPDCI estimates the dominance between indicators  $i$  and  $j$ . NPDCI greater than 0 means that  $i$  dominates  $j$ . Conversely, an NPDCI less than 0 states that  $j$  is dominant over  $i$ . This captures the difference between the gross shocks transmitted from  $i$  to  $j$  and vice versa, measuring the net influence of directional connectivity (Antonakakis et al., 2020).

#### 4. FINDINGS AND DISCUSSIONS

Firstly, we approach the analyses from a linear perspective. However, since the presence of features such as leptokurtic, excessive kurtosis, non-normal distribution, autocorrelation, and heteroscedasticity in the variables strengthens the possibility of non-linearity of the variables, we investigate whether the variables are linear or not with the BDS non-linearity test and present the findings obtained in Table 3.

**Table 3: BDS (Non)linearity Estimate Results**

	$\lambda=2$	$\lambda=3$	$\lambda=4$	$\lambda=5$	$\lambda=6$
<b>SP5F3UP</b>	0.028920***	0.062702***	0.088105***	0.104058***	0.112714***
<b>SPGBI</b>	0.018524***	0.034281***	0.045792***	0.053551***	0.057043***
<b>SPGSCEE</b>	0.013698***	0.026450***	0.036132***	0.041277***	0.042647***
<b>SPGTCED</b>	0.018963***	0.040975***	0.057020***	0.069066***	0.075527***
<b>SPXESRP</b>	0.028287***	0.061740***	0.086835***	0.102719***	0.111296***
<b>TXCT</b>	0.024248***	0.051454***	0.072848***	0.086483***	0.093829***
<b>W1SGI</b>	0.020415***	0.041965***	0.060033***	0.070676***	0.075034***

Note: We applied the BDS test to the residuals of the VAR(1) models.  $\lambda$  represents to the embedding dimensions. \*\*\* demonstrates statistical significance at the 1% level.

According to the BDS test results, the fact that the probability values of all variables are less than 1% significance level for all dimensions confirms that the probability distributions of the error terms obtained from the linear model are not independent and that there is a non-linear relationship between the indicators. Therefore, the research should be carried out using non-linear models. Accordingly, we apply the TVP-VAR connectedness technique to the analyses and display the results on the total connectedness between TVEPU and green assets in Table 4.

**Table 4: Total Connectedness between TVEPU and Green Assets**

	SPGBI	W1SGI	SPXESRP	SP5F3UP	SPGSCEE	TXCT	SPGTCED	RTVEPU	FROM
<b>SPGBI</b>	66.25	8.33	4.84	4.95	2.44	4.31	6.67	2.21	33.75
<b>W1SGI</b>	3.9	30.52	21.64	21.71	1.89	7.72	11.73	0.89	69.48
<b>SPXESRP</b>	1.93	20.33	29.43	29.19	1.42	7.98	8.84	0.88	70.57
<b>SP5F3UP</b>	1.94	20.19	29	29.23	1.45	8.23	9.08	0.86	70.77
<b>SPGSCEE</b>	2.49	4.28	3.42	3.5	78.74	2.65	2.86	2.06	21.26
<b>TXCT</b>	2.58	10.04	11.48	11.92	1.71	46.09	15.02	1.16	53.91

<b>SPGTCED</b>	3.95	14.54	11.93	12.35	1.6	14.49	40.21	0.92	59.79
<b>RTVEPU</b>	2.48	1.91	1.83	1.81	1.9	1.9	1.67	86.5	13.5
<b>TO</b>	19.27	79.63	84.14	85.42	12.42	47.29	55.89	8.98	393.03
<b>Inc.Own</b>	85.52	110.15	113.57	114.65	91.16	93.37	96.09	95.48	cTCI/TCI
<b>NET</b>	-14.48	10.15	13.57	14.65	-8.84	-6.63	-3.91	-4.52	56.15/49.13

According to Table 4, the TCI is 49.13. This result demonstrates that the spillover effect between markets is moderate. The spillover contribution of TVEPU to other markets is 8.98%. Therefore, the power of this index to affect other indices is at the lowest level. The 85.42% spillover contribution of the fossil fuel reserves free index to other indices emphasises that this market has the most influence on other markets. In addition, according to the net spillover index values, the net spillover indices for Fossil Fuel Reserves Free (SP5F3UP), Environmental and Social Responsibility (SPXESRP) and Dow Jones Sustainability (W1SGI) indices have positive values with 14.65%, 13.57% and 10.15%, respectively. This result implies that these markets are net transmitters of systematic shocks. The GB index (SPGBI) also received the most shocks from other markets, with a net spillover index of -14.48. This market is followed by CEAs (SPGSCEE), Renewable Energy and Clean Technology (TXCT), TVEPU and Global Clean Energy (SPGTCED) markets with net spillover indices of -8.84, -6.63, -4.52 and -3.91, respectively. In other words, these markets are most exposed to other markets and are net receivers of systematic shocks. Figure 2 is a graphical illustration of the dynamic TCI.

**Figure 2: Dynamic Total Connectedness Index**

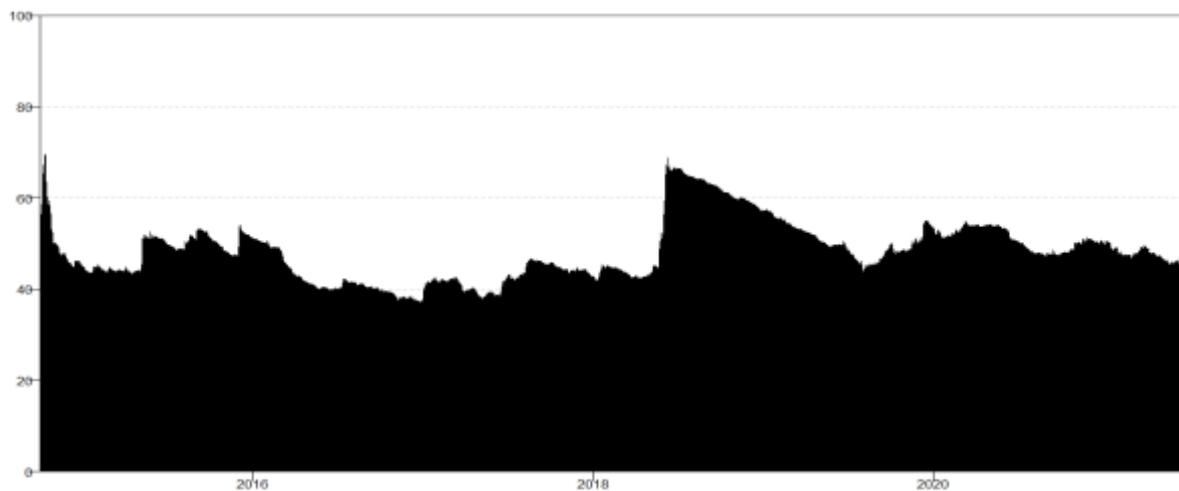
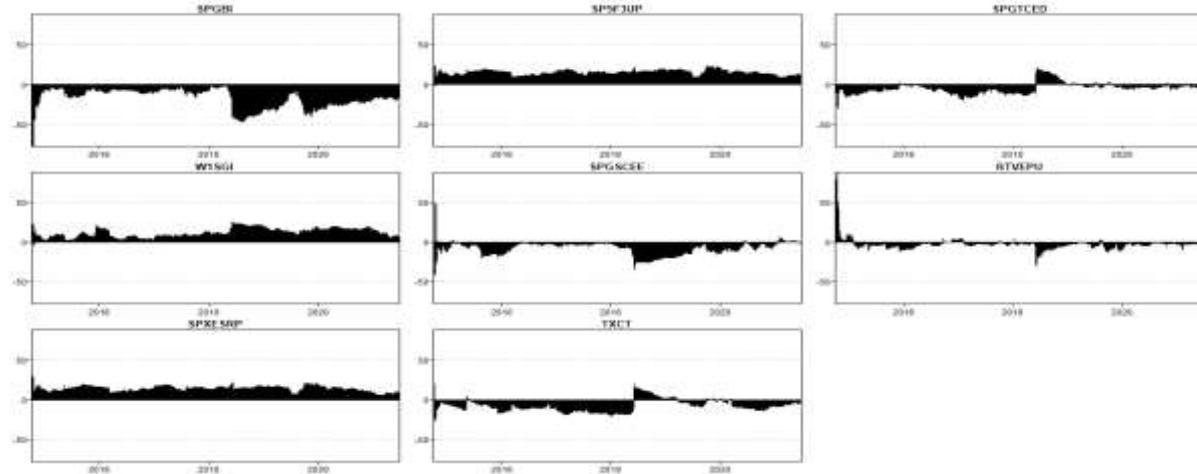


Figure 2 demonstrates that the sensitivity of the spillover effects between green equity markets, GB markets and TVEPU increases significantly under extreme positive and extreme adverse shocks. At the same time, extreme spillover effects between these markets are significantly amplified by major international events and news, such as the civil war in Syria, the annexation of Crimea to Russia, the US-China trade war, the Ferguson events, the election of Donald Trump as US president, the Ebola and COVID-19 outbreaks, and the Russia-Ukraine war. This is because crises affect socio-economic conditions, which in turn affect financial markets. Figure 3 visualises the results of the NTDCI.

Figure 3: Time-Varying Net Total Directional Interconnectedness Index



In the NTDC Index graph, the coloured areas above the zero point indicate the shocks transmitted at the relevant date or period, in contrast to the coloured areas below zero, which represent the shocks received at the relevant date or period. According to Figure 3, SP5F3UP, W1SGI and SPXESRP variables are positive for almost the entire sample period, whereas the SPGBI variable follows a negative path. These findings mean that the GB market is a net shock receiver, in contrast to the Fossil Fuel Reserves Free, Dow Jones Sustainability and Environmental and Social Responsibility markets, which are net shock transmitters. The net spillovers of SPGTCEI, RTVEPU, SPGSCEE and TXCT change over time. Indeed, Renewable Energy and Clean Technology and Global Clean Energy markets have been net shock receivers until 2019. However, they acted as net shock transmitters until the second half of 2019, with positive shocks arising from global events and news, such as the trade wars between the China and US and returned to the net shock receiver position with the influence of global news and events like the COVID-19 outbreak. Similarly, TVEPU reacted positively to events and developments such as the civil war in Syria and the annexation of Crimea to Russia and continued as a shock transmitter in the first quarter of 2015. It has been a shock receiver since the second quarter of 2015 with the impact of news and developments such as the Ferguson events and the migrant crisis. Lastly, although the CEAs market was a shock receiver until 2023, it became a shock transmitter by reacting positively to events and news, such as the FED's interest rate hike. Figure 4 contains the results of the NPDCI.

Figure 4: Net Pairwise Directional Interconnectedness Index

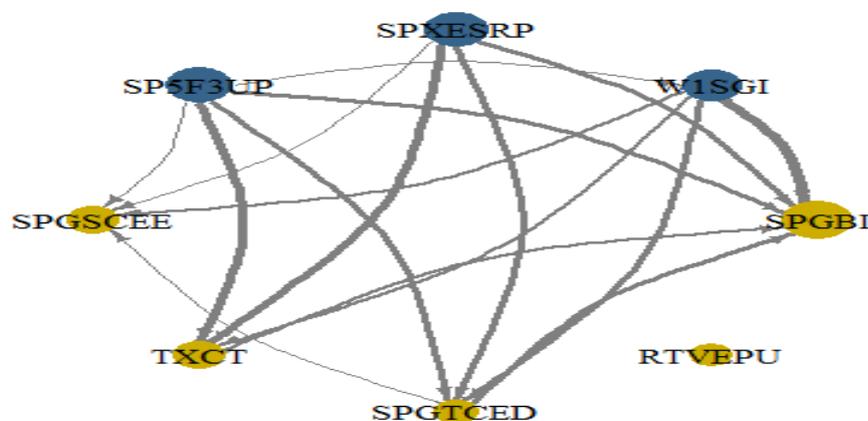


The NPDC Index plots show a low nexus level between the TVEPU index and GSs and GBs in the period under consideration. In other words, there is a shallow connection between the change in the TVEPU index and GB, Sustainability World, CEAs, Renewable Energy and Clean Technology, Fossil Fuel Reserves Free, Environmental and Social Responsibility and Global Clean Energy indices returns over the entire period considered. This result implies that GSs and GBs returns are only marginally affected by the change in the TVEPU index over the sample period.

There is a strong dependence between the returns of all other green assets except the GB index. In addition, the correlation level between these index returns is also quite high. However, although there is a low correlation between GS returns and

GB returns, this relationship has increased with the COVID-19 pandemic period. Lastly, Figure 5 reports the network connectedness index results between variables.

**Figure 5: Network Connectedness Index**



Graph 5 represents the connectedness between TVEPU and green market assets through network plots. The blue dots in the graph indicate the variables that transmit shocks, while the yellow dots refer to the variables that receive shocks. Moreover, the dots' sizes show the spillover effects' size. In the graph, the arrows outside the dots define the direction of the connectedness, and the thickness of the lines, along with the arrows, define the magnitude of the connectedness. Network plots also confirm that the interaction between TVEPU and green market assets is not remarkable. Figure 5 demonstrates a substantial shock transmission from the Fossil Fuel Reserves Free and Environmental and Social Responsibility indices to the Renewable Energy and Clean Technology, GBs and Global Clean Energy indices. However, the magnitude of the shock transmitted to the CEAs index is smaller than the others.

Similarly, while there is a robust shock transmission from the Dow Jones Sustainability indices to the GB and Global Clean Energy indices, the transmission of shocks to the CEAs and Renewable Energy and Clean Technology indices is relatively tiny. Additionally, medium-sized shocks from the Renewable Energy and Clean Technology and Global Clean Energy indices impact the GB index during specific periods. Finally, the Global Clean Energy index influences the CEAs index through relatively low-magnitude shocks during specific periods.

## 5. CONCLUSION AND IMPLICATIONS

Recently, interest in green investment assets such as GS and GB has increased intensively. Despite this, there are ongoing discussions in the economics and finance literature on their effectiveness in risk management, especially as a protection, safe-haven, and diversification strategy against EPU. This research seeks to examine the dynamic nexus between TVEPU and the returns of green assets, specifically focusing on their potential as hedges and safe havens. In doing so, this paper investigates the existence of a dynamic connectivity between changes in the TVEPU index and the returns of various indices, including GB, CEAs, Environmental and Social Responsibility, Renewable Energy and Clean Technology, Fossil Fuel Reserves Free and Global Clean Energy, for the period from October 1, 2014, to September 30, 2024, utilised TVP-VAR models.

The major findings of this research can be listed as follows. First, the Fossil Fuel Reserves Free index exerts the most significant influence on other indices, while the TVEPU index has the least impact. Second, exceptionally optimistic and pessimistic shocks from international events and news significantly heighten the sensitivity of spillover effects between green asset returns and TVEPU. Third, the GB market is a net shock receiver, while the Fossil Fuel Reserves Free, Sustainability World, and Environmental and Social Responsibility indices function as net shock transmitters. The net spillovers of the TVEPU, Global Clean Energy, CEAs and Renewable Energy and Clean Technology indices fluctuate over time. Fourth, GS and GB returns are only mildly influenced by changes in the TVEPU index. Finally, at the time-varying level, the GBs, Global Clean Energy, CEAs and Renewable Energy and Clean Technology indices are the most affected by shocks from other indices. These results align with the results of Haq et al. (2021), Su et al. (2023), Aloui et al. (2024), and Wang et al. (2024).

Empirical results provide many noteworthy suggestions for investors and policymakers: First, the results suggest that investors with a strong focus on environmental factors can enhance their diversification benefits by including GBs and GSs in their portfolios. This diversification advantage also strengthens policymakers' confidence in scaling the GB market to promote environmental responsibility. Second, when EPU is high, GSs tend to react more strongly than GBs. In such scenarios, investors need to use the safe-haven nature of GBs to protect themselves from the volatility of GSs. Since GBs are typically long-run

investments that do not respond immediately to policy changes, EPU has less impact on their short-run returns. This fact makes it a good investment tool for managing assets and more stable due to its long-term sustainability objectives. Moreover, the hedging ability of GBs over green GSs is revealed when the green stock market experiences an extreme decline due to a rise in EPU. Third, the findings may guide market actors to optimise their portfolios promptly during extreme shocks. Additionally, as market uncertainty can help governments predict future economic fluctuations effectively, governments can achieve win-win objectives such as green and low-carbon development. Finally, due to the notable influence of the EPU on renewable energy stocks, policymakers should increase the degree of clarity and transparency in policy decisions to reduce potential adverse effects on the green investment sector.

This paper has some limitations that could benefit future research. For example, while this research confirms the time-varying dynamic connectivity between TVEPU and selected green assets, it does not examine the interaction across different frequencies and quantiles. These aspects could offer valuable insights and serve as a direction for future studies.

## REFERENCES

- Adebayo, T. S., Özkan, O., Sofuoğlu, E., & Usman, O. (2024). The time-frequency-quantile causal impact of Cable News-based Economic Policy Uncertainty on major assets returns. *Investment Analysts Journal*, 1-18. <https://doi.org/10.1080/10293523.2024.2358589>
- Adetokunbo, A. M., & Mevhare, A. S. (2024). The interconnectivity between green stocks, oil prices, and uncertainty surrounding economic policy: indications from the United States. *SN Business & Economics*, 4(2), 22-35. <https://doi.org/10.1007/s43546-023-00617-y>
- Aloui, C., Ben Hamida, H., & Yildirim, R. (2024). Green Bonds and Clean Energy Stocks: Safe Havens Against Global Uncertainties? A Wavelet Quintile-Based Examination. *S&P Global Market Intelligence*, <http://dx.doi.org/10.2139/ssrn.4933708>
- Antonakakis, N., Chatziantoniou, I., & Gabauer, D. (2020). Refined measures of dynamic connectedness based on time-varying parameter vector autoregressions. *Journal of Risk and Financial Management*, 13(4), 84-95. <https://doi.org/10.3390/jrfm13040084>
- Baker, S. R., Bloom, N., & Davis, S. J. (2016). Measuring economic policy uncertainty. *The quarterly journal of economics*, 131(4), 1593-1636. [doi:10.1093/qje/qjw024](https://doi.org/10.1093/qje/qjw024)
- Bansal, R., & Shaliastovich, I. (2010). Confidence risk and asset prices. *American Economic Review*, 100(2), 537-541. <https://doi.org/10.1257/aer.100.2.537>
- Bergbrant, M. C., & Bradley, D. (2022). Did they just say that? Using AI to extract economic policy uncertainty from cable news networks (SSRN Scholarly Paper 4059681). <https://doi.org/10.2139/ssrn.4059681>
- Berrou, R., Dessertine, P., & Migliorelli, M. (2019). An overview of green finance. In M. Migliorelli, & P. Dessertine (Eds.), *The Rise of Green Finance in Europe*. Palgrave Studies in Impact Finance. Cham: Palgrave Macmillan. [https://doi.org/10.1007/978-3-030-22510-0\\_1](https://doi.org/10.1007/978-3-030-22510-0_1)
- Braouezec, Y., & Joliet, R. (2019). Time to invest in corporate social responsibility and the value of CSR operations: The case of environmental externalities. *Managerial and Decision Economics*, 40(5), 539-549. <https://doi.org/10.1002/mde.3024>
- Broadstock, D.C., Chatziantoniou, I., Gabauer, D. (2022). Minimum Connectedness Portfolios and the Market for Green Bonds: Advocating Socially Responsible Investment (SRI) Activity. In: Floros, C., Chatziantoniou, I. (eds) *Applications in Energy Finance*. Palgrave Macmillan, Cham- Switzerland. [https://doi.org/10.1007/978-3-030-92957-2\\_9](https://doi.org/10.1007/978-3-030-92957-2_9)
- Campbell, J. Y., & Shiller, R. J. (1991). Yield spreads and interest rate movements: A bird's eye view. *The Review of Economic Studies*, 58(3), 495-514.
- Diebold, F. X., & Yilmaz, K. (2014). On the network topology of variance decompositions: Measuring the connectedness of financial firms. *Journal of econometrics*, 182(1), 119-134. <https://doi.org/10.1016/j.jeconom.2014.04.012>
- Haq, I. U., Chupradit, S., & Huo, C. (2021). Do green bonds act as a hedge or a safe haven against economic policy uncertainty? Evidence from the USA and China. *International Journal of Financial Studies*, 9(3), 40-56. <https://doi.org/10.3390/ijfs9030040>
- Hong, H., & Kostovetsky, L. (2012). Red and blue investing: Values and finance. *Journal of financial economics*, 103(1), 1-19. <https://doi.org/10.1016/j.jfineco.2011.01.006>
- Hong, J., Crichton, W., Zhang, H., Fu, D. Y., Ritchie, J., Barenholtz, J., Hannel, B., Yao, X., Murray, M., Moriba, G., Agrawala, M., & Fatahalian, K. (2021). Analysis of Faces in a Decade of US Cable TV News. *Proceedings of the 27th ACM SIGKDD Conference on Knowledge Discovery & Data Mining*, 3011-3021. <https://doi.org/10.1145/3447548.3467134>
- Iacobuță, G. I., Brandi, C., Dzebo, A., & Duron, S. D. E. (2022). Aligning climate and sustainable development finance through an SDG lens. The role of development assistance in implementing the Paris Agreement. *Global Environmental Change*, 74, 102509. <https://doi.org/10.1016/j.gloenvcha.2022.102509>
- Kazlauskienė, V., Draksaitė, A., & Melnyk, L. (2017). September). Green investment financing alternatives. In *Economic Science for Rural Development Conference Proceedings*, 46, 1691-3078.
- Koop, G., Pesaran, M. H., & Potter, S. M. (1996). Impulse response analysis in nonlinear multivariate models. *Journal of Econometrics*, 74(1), 119-147.

- Koop, G., & Korobilis, D. (2013). Large time-varying parameter VARs. *Journal of Econometrics*, 177(2), 185-198. <https://doi.org/10.1016/j.jeconom.2013.04.007>
- Koop, G., & Korobilis, D. (2014). A new index of financial conditions. *European Economic Review*, 71, 101-116. <https://doi.org/10.1016/j.euroecorev.2014.07.002>
- Lin, B., & Su, T. (2023). Uncertainties and green bond markets: Evidence from tail dependence. *International Journal of Finance & Economics*, 28(4), 4458-4475. <https://doi.org/10.1002/ijfe.2659>
- Luo, Y., & Zhang, C. (2020). Economic policy uncertainty and stock price crash risk. *Research in International Business and Finance*, 51, 101112. <https://doi.org/10.1016/j.ribaf.2019.101112>
- Madaleno, M., Dogan, E., & Taskin, D. (2022). A step forward on sustainability: The nexus of environmental responsibility, green technology, clean energy and green finance. *Energy Economics*, 109, Article 105945. <https://doi.org/10.1016/j.eneco.2022.105945>
- McCollum, D. L., Zhou, W., Bertram, C., De Boer, H. S., Bosetti, V., Busch, S., ... & Riahi, K. (2018). Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals. *Nature Energy*, 3(7), 589-599. <https://doi.org/10.1038/s41560-018-0179-z>
- Nagar, V., Schoenfeld, J., & Wellman, L. (2019). The effect of economic policy uncertainty on investor information asymmetry and management disclosures. *Journal of Accounting and Economics*, 67(1), 36-57. <https://doi.org/10.1016/j.jacceco.2018.08.011>
- Nakajima, J. (2011). Time-varying parameter VAR model with stochastic volatility: An overview of methodology and empirical applications. *Monetary and Economic Studies*, 29, 107-142.
- Pástor, L., & Veronesi, P. (2013). Political uncertainty and risk premia. *Journal of Financial Economics*, 110(3), 520-545. <https://doi.org/10.1016/j.jfineco.2013.08.007>
- Pham, L., & Nguyen, C. P. (2022). How do stock, oil, and economic policy uncertainty influence the green bond market? *Finance Research Letters*, 45, 102128. <https://doi.org/10.1016/j.frl.2021.102128>
- Su, X., Guo, D., & Dai, L. (2023). Do green bond and green stock markets boom and bust together? Evidence from China. *International Review of Financial Analysis*, 89, 102744. <https://doi.org/10.1016/j.irfa.2023.102744>
- Syed, A. A., Ahmed, F., Kamal, M. A., Ullah, A., & Ramos-Requena, J. P. (2022). Is there an asymmetric relationship between economic policy uncertainty, cryptocurrencies, and global green bonds? Evidence from the United States of America. *Mathematics*, 10(5), 720-735. <https://doi.org/10.3390/math10050720>
- Wang, X., Li, J., Ren, X., & Lu, Z. (2022). Exploring the bidirectional causality between green markets and economic policy: evidence from the time-varying Granger test. *Environmental Science and Pollution Research*, 29(58), 88131-88146. <https://doi.org/10.1007/s11356-022-21685-x>
- Wang, K. H., Su, C. W., Umar, M., & Lobonț, O. R. (2023). Oil price shocks, economic policy uncertainty, and green finance: a case of China. *Technological and Economic Development of Economy*, 29(2), 500-517. <https://doi.org/10.3846/tede.2022.17999>
- Wang, Y., Yan, W., & Wang, B. (2024). Green bond and green stock in China: The role of economic and climate policy uncertainty. *The North American Journal of Economics and Finance*, 74, 102228. <https://doi.org/10.1016/j.najef.2024.102228>
- Wei, W., Hu, H., & Chang, C. P. (2021). Economic policy uncertainty and energy production in China. *Environmental Science and Pollution Research*, 28(38), 53544-53567. <https://doi.org/10.1007/s11356-021-14413-4>
- Wei, P., Qi, Y., Ren, X., & Duan, K. (2022). Does economic policy uncertainty affect green bond markets? Evidence from wavelet-based quantile analysis. *Emerging Markets Finance and Trade*, 58(15), 4375-4388. <https://doi.org/10.1080/1540496X.2022.2069487>
- Xi, Z., Wang, H., Sun, Q., & Ma, R. (2023). Uncovering the asymmetric impacts of economic policy uncertainty on green financial markets in China. *Environmental Science and Pollution Research*, 30(60), 126214-126226. <https://doi.org/10.1007/s11356-023-31122-2>
- Xia, Y., Shi, Z., Du, X., Niu, M., & Cai, R. (2023). Can green assets hedge against economic policy uncertainty? Evidence from China with portfolio implications. *Finance Research Letters*, 55, 103874. <https://doi.org/10.1016/j.frl.2023.103874>
- Urom, C., Mzoughi, H., Ndubuisi, G., & Guesmi, K. (2022). Dynamic dependence between clean investments and economic policy uncertainty. *UNU-MERIT. UNU-MERIT Working Papers No. 027*, <https://www.merit.unu.edu/publications/wppdf/2022/wp2022-027.pdf> (Date accessed: October 26, 2024).

## MACROECONOMIC EFFECTS OF CRUDE OIL SHOCKS IN SOUTH AFRICA: A MARKOV SWITCHING INTERCEPTS VAR APPROACH

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**Dumisani Pamba**

University of KwaZulu-Natal, School of Accounting, Economics and Finance, Durban, South Africa.

[kanye.pamba@gmail.com](mailto:kanye.pamba@gmail.com), ORCID: 0000-0002-1911-5671

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### ABSTRACT

**Purpose-** This study examines how fluctuations in crude oil price shocks affect South African macroeconomic indicators.

**Methodology-** The study employed the Markov Switching Intercepts VAR (MSI-VAR) approach to capture the dynamic and nonlinear effects of crude oil prices on key macroeconomic indicators, including real GDP growth, inflation, exchange rates, interest rates, and the current account balance. The study applied two regime models: regime one for times of growth and regime two for times of recession. Based on this framework, macroeconomic indicators were analyzed from 2000 Q1 to 2023 Q4 for their varying responses to oil price shocks.

**Findings-** It is evident that South Africa's economy is susceptible to changes in crude oil prices. A crude oil shock has a negative impact on real GDP growth during economic growth (Regime One). In contrast, oil shocks lead to an increase in real GDP growth during recessions (Regime Two). Moreover, crude oil shocks result in a decrease in inflation across both regimes. A crude oil shock has a positive effect on exchange rates and interest rates in Regime One, but a negative effect in Regime Two. Furthermore, crude oil shocks adversely impact the current account balance in both regimes.

**Conclusion-** Crude oil shocks affect the economy differently depending on the prevailing conditions. Therefore, policymakers must evaluate these conditions and implement suitable policies to reduce adverse effects. Monitoring and responding to changes in the global oil market is crucial for mitigating negative consequences and fostering stability.

**Keywords:** Macroeconomic variables, oil price shocks, Markov Switching Intercepts VAR (MSI-VAR), South Africa

**JEL Codes:** E32, F31, Q43

## 1. INTRODUCTION

The impact of crude oil price shocks on the macroeconomic activity of global economies is well established. Policymakers and scholars have highlighted the role these shocks play in shaping growth fundamentals (Van Eyden et al., 2019; Kirca et al., 2020; Magazzino et al., 2021). Rerezki et al. (2017) explain that fluctuations in crude oil prices are driven by the interplay between supply and demand in global commodities markets. Given South Africa's heavy reliance on oil imports for energy production, the effects of oil price shocks on its economy can be significant. This dependence on oil for transportation, coupled with its impact on the cost of living, makes South Africa particularly vulnerable to price changes. A strong correlation exists between oil shocks and various macroeconomic variables (Sheng, 2020). Key macroeconomic factors, including inflation, interest rates, currency values, and overall economic growth, are directly affected by global crude oil price fluctuations (Azad and Serletis, 2020; Khan et al., 2020; Yildirim and Arifli, 2021). Consequently, any oil price shock is likely to impact the South African economy significantly.

The impact of oil price fluctuations can be observed through various channels. Changes in crude oil prices lead to increased gasoline costs (Jiang and Liu, 2021), which constitute a significant portion of the Consumer Price Index (CPI) in South Africa. Rising oil prices contribute to cost-push inflation, driving up expenses in the manufacturing, transportation, and energy sectors. Increasing costs for consumers result in higher prices for goods and services, which raises the inflation rate overall. Additionally, changes in oil prices have a substantial effect on monetary and fiscal policy (Saddiqui et al., 2018). According to Rafiq et al. (2009), oil price volatility significantly influences investment and currency rates. The rand (ZAR) is affected by fluctuations in oil prices in South Africa. Increasing oil prices can weaken the ZAR since the country will need to allocate more resources to oil imports, negatively impacting the trade balance. Conversely, a decline in oil prices could improve the trade imbalance by strengthening the currency as import costs decrease. Higher oil prices also raise production costs for fuel-dependent industries, which can hinder economic growth (Cheng et al., 2019). The sectors most vulnerable to these price changes in South Africa include transportation, manufacturing, and mining. On the other hand, falling oil prices can stimulate

economic growth by reducing manufacturing and transportation costs, boosting consumer spending, and enhancing sectoral profitability. Consequently, South Africa's economy is highly sensitive to oil price fluctuations. Elevated oil prices have the potential to worsen the country's trade imbalance and impede economic growth. In contrast, decreases in oil prices can lead to increased industry profitability and lower production costs, fostering economic expansion. To effectively manage the economic impacts, South African officials must closely monitor and anticipate fluctuations in oil prices.

Numerous studies present conflicting evidence regarding the relationship between high oil prices and various macroeconomic effects. Jiang and Liu (2021) demonstrated the asymmetric effects of crude oil price uncertainty on shock prices using the NARDL model. Aloui et al. (2018), employing a unique wavelet method, found a positive and non-homogeneous association between oil prices and production growth in Saudi Arabia. Besso et al. (2017), utilizing a panel VAR model, concluded that oil prices have a significant long-term negative impact on GDP growth. During a decline in oil prices, Cheng et al. (2019) found that real GDP and investment are negatively affected by an increase in oil prices. Miamo and Achuo (2021) identified a two-way causal relationship between GDP and crude oil prices. Chisadza et al. (2016) argue that both oil demand and oil-specific demand shocks positively influence production, although shocks to oil supply do not significantly impact output. Nazlioglu et al. (2019), using Toda-Yamamoto causality, found a strong transmission mechanism from oil prices to consumer prices, alongside varying causal relationships between exchange rates and interest rates. This suggests that consumer prices may mediate the link between oil prices and monetary policy. According to Hollander et al. (2018), oil price shocks significantly and durably affect domestic output and consumption, with rising oil costs leading to declines in both areas. This highlights the economy's vulnerability to fluctuations in oil prices. The research suggests that changes in oil prices can substantially influence the overall economy, affecting not only consumer prices but also interest rates and currency values. It underscores the importance of closely monitoring oil price fluctuations and their potential implications for monetary policy and economic stability. These studies collectively stress the need to understand the complex dynamics of oil price movements to anticipate and mitigate risks to economic stability. Policymakers are encouraged to incorporate non-linear and regime-switching models into their analyses to better prepare for the impacts of oil price shocks, enabling informed decisions that protect the economy from adverse outcomes. A more nuanced approach to studying oil price fluctuations is essential for a comprehensive understanding of their implications for monetary policy and economic stability.

This study contributes to the existing literature in several significant ways. First, it examines the macroeconomic effects of crude oil shocks in South Africa using the Markov Switching Intercepts VAR Model (MSI-VAR). Understanding how crude oil shocks influence a country's macroeconomic variables is particularly important for oil-importing nations like South Africa. To the author's knowledge, this is the first study to explore regime switching in the context of crude oil shocks in South Africa. Second, the MSI-VAR approach facilitates a more comprehensive analysis of the dynamic relationships between crude oil shocks and various macroeconomic variables within the South African economy. This sophisticated econometric tool enables researchers to identify regime changes in the economy, such as transitions between high-growth and low-growth periods, and to analyze how these regimes interact with external shocks like fluctuations in oil prices. Overall, this study provides a deeper understanding of how crude oil shocks affect macroeconomic variables in South Africa, enhancing our knowledge of the transmission mechanisms involved. The findings offer valuable insights for both policymakers and researchers.

Following the introduction, Section 2 presents a literature review, Section 3 details the data and methodology used in the analysis, Section 4 presents the study's findings, Section 5 discusses the results, and Section 6 concludes with the implications.

## **2. LITERATURE REVIEW**

In a recent publication, researchers examined how oil price shocks affect industrialized and emerging countries. The impact of oil price shocks on South Africa, which is heavily dependent on oil imports, is scarcely explored empirically.

### **2.1. International Studies**

Using the vector autoregressive model, Zulfigarov and Neuenkirch (2020) investigated the link between oil price fluctuations and economic activity in Azerbaijan from 2002 to 2018. It was found that other macroeconomic factors responded differently to price volatility and an increase in inflation was associated with changes in oil prices.

Using the VAR model, Yildirim and Arifli (2021) investigated the impact of oil price shocks on the Azerbaijani economy from 2006 to 2018. Trade balances are affected, currencies weaken, inflation is raised, and economic activity is generally slowed by negative oil price shocks.

Azad and Serletis (2020) used statistical models to investigate how oil price volatility affects economic activity. They found that the GDP of the seven emerging market (EM7) nations is significantly impacted by oil price uncertainty. Additionally, they discovered that global crude oil output is adversely affected by oil price volatility.

Using a wavelet-based quantile regression model, Khan et al. (2020) investigated how industrial production and gas, and oil prices are related. They found that, in the short run, natural gas has a negative association with industrial production, while crude oil has a positive one.

Omojolaibi and Egwaikhide (2013) used data from the United States, China, and Japan to examine the effects of crude oil price changes on GDP growth and inflation rates. They found that rising oil prices negatively impacted GDP growth in China but positively influenced GDP growth in the US and Japan. They concluded that developed net oil importers like the US and Japan are less affected by changes in oil prices than emerging economies like China regarding GDP growth rates.

Using secondary data from 2001 to 2022, Alawadhi and Longe's (2024) study investigates the effects of oil price shocks on Kuwaiti macroeconomic indicators. The study examines how Kuwaiti macroeconomic variables respond to oil price shocks using the vector autoregression (VAR) approach. The study reveals that oil price shocks significantly impact Kuwait's macroeconomic variables, emphasizing the need for more policy developments and risk hedging frameworks to mitigate their impact.

The effect of changes in oil prices on macroeconomic variables in Indonesia was examined by Lizein et al. (2024). A structural vector autoregressive (SVAR) model was applied to yearly Indonesian data from 1990 to 2021. The results reveal that shocks to oil prices significantly affect GDP, inflation, and exchange rates. Moreover, oil price shocks adversely affect the index of industrial production and interest rates.

The impact of oil price shocks on real output, inflation, and the real exchange rate in Thailand, Malaysia, Singapore, the Philippines, and Indonesia (ASEAN-5) is examined by Basnet and Upadhyaya (2015) using a structural vector autoregressive (SVAR) approach. ASEAN-5 economies are not affected by long-term fluctuations in oil prices or their ability to explain significant changes in the real exchange rate or inflation.

## **2.2. South Africa Studies**

Fasanya and Makanda's (2024) study examined the relationship between oil shocks and macroeconomic policy uncertainty in South Africa from 1990 to 2022, revealing a weak correlation overall. The strongest relationships emerged at both the lower and higher quantiles. At lower quantiles, macroeconomic policy uncertainty acted as a net receiver, while at medium and upper quantiles, political and economic policy uncertainty served as net transmitters.

Hollander et al. (2018) investigate how major macroeconomic indicators for South Africa a net oil importer is affected by shocks to global (real) oil prices. Foreign real oil price shocks significantly drive output, inflation, and interest rates in both the short and long term, as they have a lasting impact on local production and consumption activities. These oil price shocks can create a trade-off between stabilizing inflation and output, leading to periods of monetary policy tightening that hinder economic recovery in South Africa.

Marna et al. (2007) present a macro-micro paradigm to examine how oil prices impact the global economy and the South African economy. They employ a micro-simulation study and a highly disaggregated general equilibrium model to predict changes in prices, employment, and earnings. They estimate that a 125% increase in crude oil and refined petroleum prices will result in a 2% decrease in employment, a 7% drop in household spending, and a 2% rise in unemployment. Rising oil prices widen the wealth gap, affecting low- and medium-skilled workers and households with higher skill levels.

## **3. DATA AND METHODOLOGY**

### **3.1. Data Source**

Historical time series data from 2000Q1 to 2023Q4 on crude oil prices, RGDP, inflation, exchange rates, interest rates, and the current account balance was obtained from the South African Reserve Bank (SARB).

### **3.2. Explanation of Key Components**

#### **Endogenous Variables**

**GDP growth rate:** Higher oil prices typically slow economic growth by raising production costs for industries that depend on fuel. In South Africa, sectors like mining, manufacturing, and transportation are especially sensitive to fluctuations in oil prices. On the other hand, a decline in oil prices can stimulate economic growth by reducing production and transportation costs, enhancing profitability across various sectors, and boosting consumer spending. The impact of oil shocks on GDP growth is expected to vary based on prevailing economic conditions.

**Inflation:** Direct impacts of crude oil price shocks lead to higher fuel prices, a significant component of South Africa's Consumer Price Index (CPI). Cost-push inflation caused by rising oil prices increases transportation, manufacturing, and energy costs. As a result of higher fuel costs, businesses often pass these costs on to their consumers, increasing prices for goods and services, further increasing inflationary pressures. Oil shocks are expected to have varying effects on inflation depending on economic conditions.

**Exchange Rates:** Oil price fluctuations significantly impact the South African rand (ZAR). When oil prices rise, the ZAR often weakens because the country must spend more on oil imports, which negatively affects the trade balance. In contrast, when

oil prices decline, the ZAR typically strengthens as import costs decrease, leading to an improvement in the trade deficit. The effects of oil shocks on the exchange rate are expected to vary based on prevailing economic conditions.

**Interest Rates:** Interest rates are frequently adjusted by the South African Reserve Bank (SARB) to combat inflationary pressures caused by rising oil prices. When oil price shocks lead to higher inflation, the SARB may raise interest rates to ensure price stability, which can, in turn, slow economic activity. In response to oil shocks, interest rates are expected to vary depending on economic conditions.

**Current Account Balance:** Since South Africa is relying heavily on oil imports for its current account balance, crude oil price fluctuations have significant effects. When oil prices rise, the current account balance typically worsens as South Africa spends more on imports, leading to increased inflation, reduced consumer spending, and slower economic growth. Conversely, when oil prices decline, the current account balance improves, benefiting the economy through lower inflation and increased consumer spending. Oil price shocks are expected to negatively impact the current account balance in both economic conditions.

### Exogeneous Variable

**Crude Oil Shocks:** This refers to sudden and significant changes in crude oil prices, which can result from supply-side disruptions, such as geopolitical instability, shifts in demand, or speculative activities. Crude oil prices are a key input for many industries, so fluctuations can have a significant impact on the economy.

### 3.3. Unit Root

The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests play a vital role in identifying unit roots in time series data, which helps determine whether variables are stationary or non-stationary. These tests enable us to evaluate the long-term relationships between variables and the risk of spurious regression results. In this study, the unit root and stationarity tests form the basis for our Markov Switching Intercepts VAR approach, allowing us to effectively model the dynamic effects of crude oil shocks on the South African economy.

### 3.4. Econometric Model

#### Markov Switching Intercepts VAR (MSI-VAR) Model

The MSI-VAR model enhances the traditional VAR model by accounting for changes in the relationships between variables based on different economic regimes, such as periods of growth versus recession. These regimes are represented as hidden states within a Markov process, indicating that the economy transitions between states with specific, unobservable probabilities. By integrating these hidden states into the VAR model, we can effectively capture the dynamic relationships between crude oil shocks and macroeconomic variables in South Africa. This approach provides a clearer understanding of how various economic regimes influence the transmission of oil price fluctuations to key indicators, including GDP, inflation, exchange rates, interest rates, and the current account balance. Analyzing these effects within a Markov switching framework allows us to gain valuable insights into policy implications and strategies for mitigating the macroeconomic impact of crude oil shocks in South Africa.

The formula for the Markov Switching Intercepts VAR model is as follows:

VAR(p) model for Markov-Switching Intercepts includes two regimes as follows:

Where

- $Y_t$  is an  $n \times 1$  vector of endogenous variables (for example, GDP growth, inflation, exchange rates, interest rate and current account balance) at time  $t$
- $\mu(S_t)$  is an  $n \times 1$  vector of regime-dependent intercepts, which vary with the state  $S_t$ .
- $A_1(S_t), A_2(S_t), \dots, A_p(S_t)$  are  $n \times n$  coefficient matrices that depend on the regime  $S_t$ . These capture the autoregressive relationship of the variables across  $p$  lags.
- $\epsilon_t \sim N(0, \Sigma(S_t))$  is a vector of error terms with a variance-covariance matrix  $\Sigma(S_t)$  that depends on the regime  $S_t$ .
- $S_t \in \{1, 2, \dots, k\}$  is a latent state variable (indicating the current regime at time  $t$ ). that follows a Markov process.  $k$  represents the number of regimes.

#### Regime Switching Mechanism

The Markov process governs the transitions between different regimes:

$$P(S_t = j | S_{t-1} = i) = p_{ij}$$

$p_{ij}$  is the transition probability of shifting from regime  $i$  to regime  $j$ , and a transition probability matrix summarizes these probabilities:

$$P = \begin{bmatrix} p_{11} & p_{12} & \dots & p_{1k} \\ p_{21} & p_{22} & \dots & p_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ p_{k1} & p_{k2} & \dots & p_{kk} \end{bmatrix}$$

$p_{ii}$  represents the probability of staying in regime  $i$ .

$p_{ij}$  represents the probability of transitioning from regime  $i$  to regime  $j$

## 4. FINDINGS

### 4.1. Descriptive Statistics

The findings of descriptive statistics are presented in Table 1. The average real GDP growth of 2.33% indicates a moderate level of economic expansion, while the high inflation risk mean of 112.88 suggests potential challenges to price stability. The exchange rate, with a mean of 85.69, reflects a relatively stable currency despite external economic influences. The mean interest rate of 10.79 indicates moderate borrowing costs for both businesses and consumers. A negative current account balance mean of -2.06 indicates that South Africa is importing more goods and services than it is exporting. Additionally, the average crude oil shock of 66.18 shows the significant impact fluctuating oil prices can have on the South African economy. Overall, these findings emphasize the importance of analyzing and understanding the relationship between crude oil shocks and various macroeconomic indicators in South Africa.

**Table 1: A Summary of Descriptive Statistics**

Description	RGDP	INF	EXR	IR	CAB	OIL
Mean	2.330208	112.8761	85.69135	10.79323	-2.016895	66.17688
Median	2.500000	108.0200	82.88500	10.25000	-2.793197	62.64000
Maximum	5.600000	174.9900	108.9900	17.00000	4.123380	121.3100
Minimum	-6.300000	58.14000	64.68000	7.000000	-5.836930	19.40000
Std. Deviation	2.159050	37.24312	11.99395	2.546241	2.795811	28.96720
Skewness	-1.183971	0.188697	0.282692	0.670604	0.535743	0.247786
Kurtosis	5.724747	1.604611	1.830739	2.657945	2.188086	1.978794
Jarque-Bera (JB)	52.12560	8.358145	6.747326	7.663365	7.229146	5.153816
Probability	0.000000	0.015313	0.034264	0.021673	0.026928	0.076009
Observations	96	96	96	96	96	96

Source: Authors' Estimation using Eviews 14.

Real GDP growth (RGDP) has a standard deviation of 2.159050, inflation risk is 37.24312, exchange rate risk (EXR) is 11.99395, interest rates (IR) are 2.546241, the current account balance (CAB) is 2.795811, and crude oil shocks (OIL) have a standard deviation of 28.96720. These figures indicate that the South African economy is particularly sensitive to fluctuations in crude oil prices, as reflected in the high standard deviation of the OIL variable. Additionally, the volatility in inflation and exchange rates suggests a vulnerability to external shocks, which could significantly impact economic stability. Conversely, the relatively low standard deviations of real GDP growth and interest rates indicate a degree of stability in these areas, though they may still be affected by external factors such as crude oil shocks. Overall, these descriptive statistics underscore the importance of considering the macroeconomic effects of crude oil shocks in South Africa and highlight the need for appropriate policy responses to mitigate potential risks.

The negative skewness of real GDP growth indicates a leftward tail, signaling the potential for lower-than-expected growth rates. In contrast, both inflation risk and exchange rate risk exhibit positive skewness, suggesting a rightward tail and the possibility of higher-than-expected risk levels in these areas. Similarly, interest rates and the current account balance also show positive skewness, indicating the potential for higher-than-expected rates and balances. Lastly, the skewness of crude oil shocks is slightly positive, pointing to a rightward tail and the potential for unexpected increases in oil prices that could impact the economy.

The data reveal a high kurtosis in Real GDP growth, characterized by heavy tails and a sharp peak, which indicates a higher likelihood of extreme values. In contrast, inflation risk exhibits a kurtosis of less than 3, reflecting a flatter distribution with lighter tails and fewer extreme deviations. Exchange rate risk has a kurtosis of 1.830739, indicating fewer extreme events compared to a normal distribution. It appears that interest rate movements follow a nearly normal distribution, since their kurtosis is close to 3. The current account balance demonstrates a slightly platykurtic distribution, pointing to a reduced occurrence of extreme values. Lastly, crude oil shocks present a kurtosis below 3, signifying a flatter distribution.

## 4.2. Unit Root and Stationarity Tests

Unit root and stationarity tests are crucial for assessing the stability and reliability of data when analyzing the macroeconomic effects of crude oil shocks in South Africa. By determining whether the variables display non-stationary behavior, we can gain a clearer understanding of how fluctuations in oil prices affect the economy. The results of the ADF and PP tests are shown in Table 2.

**Table 2: ADF and PP Unit Root Test Results**

Variables	ADF Test		PP Test		Status
	t-statistic	Status	t-statistic	Status	
lnRGDP	-6.430185***	I(1)	-6.904120***	I(1)	I(1)
lnINF	-4.931731***	I(1)	-10.97185***	I(1)	I(1)
lnEXR	-7.819843***	I(1)	-7.834603***	I(1)	I(1)
lnIR	-6.888212***	I(1)	-6.984926***	I(1)	I(1)
lnCAB	-4.308496***	I(1)	-4.394021***	I(1)	I(1)
lnOIL	-7.316885***	I(1)	-7.103217***	I(1)	I(1)

Note. (\*\*\*) indicate significant at 1%. All the variables are log linearized.

Source: Authors' computation using EViews 14.

The unit root tests indicate that the variables are stationary at I(1), suggesting that the data used in this study are reliable and appropriate for further analysis. Additionally, the stationarity of the variables implies that any observed trends or patterns are likely to be robust, rather than merely the result of random fluctuations. This strengthens the accuracy and significance of the conclusions drawn about the relationship between crude oil shocks and the South African economy. Overall, the results of the unit root and stationarity tests enhance the credibility and validity of the study's findings, underscoring the importance of these preliminary analyses in econometric research.

## 4.3. MSI-VAR Results

This builds on the previous work of Agyemang-Badu et al. (2024), who employed a two-regime model. In regime one, characterized by high growth, the impact of crude oil price shocks tends to be less severe, as the economy exhibits greater resilience and adaptive capacity. In contrast, regime two represents a recession, during which oil price shocks can have a more pronounced negative effect on macroeconomic variables.

Table 3 presents the coefficients of crude oil shocks and real GDP growth (RGDP). In regime one, the coefficient is -0.005581, indicating a minimal negative correlation during periods of high growth. In contrast, regime two shows a positive link with a coefficient of 0.068224, suggesting that in times of recession, crude oil shocks can contribute to an increase in economic output. This study underscores the significance of recognizing how varying economic conditions can influence the impact of external shocks, such as fluctuations in oil prices, on a nation's macroeconomic performance.

In regime one, the coefficient for crude oil shocks and inflation (INF) is -0.007537, while in regime two, it reveals a stronger negative correlation of -0.125483. This indicates that during periods of economic growth, South Africa is better equipped to absorb and mitigate the impact of oil price shocks. Conversely, during a recession, the economy becomes more vulnerable to the adverse effects of these shocks. Furthermore, the negative relationship between crude oil shocks and inflation in regime two suggests a likelihood of higher inflation rates during economic downturns. Overall, these findings offer valuable insights into the dynamic relationship between crude oil price shocks and macroeconomic variables in South Africa, which can help inform policymakers about effectively managing the economy's response to such shocks.

There is a positive relationship between crude oil shocks and the exchange rate (EXR) in regime one (0.005307), while in regime two, this relationship is negative (-0.206430). The differing reactions of the economy across these two regimes indicate that South Africa's level of economic activity significantly influences the impact of crude oil price shocks. In regime one, the positive correlation suggests that during periods of economic growth, the currency tends to strengthen in response to rising oil prices. Conversely, the negative correlation in regime two implies that during recessions, the exchange rate weakens when confronted with similar oil price shocks. This analysis offers valuable insights into the dynamic relationship between crude oil shocks and macroeconomic variables in South Africa.

There is a positive relationship between crude oil shocks and interest rates (IR) in regime one (0.004182), while in regime two, the relationship is negative (-0.002599). This indicates that during periods of high growth, the South African economy can effectively absorb and mitigate the effects of crude oil price shocks. Conversely, during a recession, the negative impact of these shocks is amplified, resulting in a more significant influence on macroeconomic variables, such as interest rates. This underscores the importance of understanding the dynamics between oil prices and macroeconomic variables under different economic conditions to manage and mitigate potential risks effectively.

Table 3: MSI-VAR Results

	RGDP	INF	EXR	IR	CAB
<b>Regime 1</b>					
<b>C</b>	5.690961 (1.59683) [ 3.56391]	9.797219 (4.52926) [ 2.16310]	6.074549 (10.2944) [ 0.59008]	4.660159 (1.32273) [ 3.52314]	0.159870 (0.86378) [ 0.18508]
<b>OIL</b>	-0.005581 (0.00327) [-1.70599]	-0.007537 (0.00928) [-0.81228]	0.005307 (0.02109) [ 0.25164]	0.004182 (0.00271) [ 1.54324]	-0.001207 (0.00177) [-0.68150]
<b>Regime 2</b>					
<b>C</b>	-2.979085 (2.99902) [-0.99335]	24.44999 (8.50749) [ 2.87394]	24.54369 (19.3410) [ 1.26900]	3.983364 (2.48458) [ 1.60323]	2.131148 (1.62336) [ 1.31280]
<b>OIL</b>	0.068224 (0.02996) [ 2.27748]	-0.125483 (0.08498) [-1.47660]	-0.206430 (0.19321) [-1.06842]	-0.002599 (0.02482) [-0.10470]	-0.026770 (0.01622) [-1.65051]
<b>Common</b>					
<b>RGDP(-1)</b>	0.938914 (0.04609) [ 20.3717]	-0.335338 (0.13072) [-2.56534]	0.143448 (0.29716) [ 0.48273]	0.224913 (0.03818) [ 5.89129]	-0.108260 (0.02495) [-4.33971]
<b>INF(-1)</b>	-0.013647 (0.00489) [-2.78936]	0.968793 (0.01388) [ 69.8128]	-0.006149 (0.03154) [-0.19498]	-0.005688 (0.00405) [-1.40361]	0.001613 (0.00265) [ 0.60923]
<b>EXR(-1)</b>	-0.008397 (0.00926) [-0.90690]	-0.032941 (0.02626) [-1.25438]	0.890416 (0.05969) [ 14.9164]	-0.044264 (0.00767) [-5.77148]	-0.003883 (0.00501) [-0.77522]
<b>IR(-1)</b>	-0.237552 (0.04990) [-4.76084]	-0.177534 (0.14152) [-1.25446]	0.292549 (0.32170) [ 0.90940]	0.910580 (0.04133) [ 22.0312]	0.027629 (0.02700) [ 1.02341]
<b>CAB(-1)</b>	0.137553 (0.03263) [ 4.21558]	-0.286752 (0.09255) [-3.09850]	0.090420 (0.21035) [ 0.42985]	0.025448 (0.02703) [ 0.94160]	0.970949 (0.01766) [ 54.9752]
<b>SIGMA</b>	0.416419 (0.06042) [ 6.89206]	0.011810 (0.12078) [ 0.09777]	0.603011 (0.28234) [ 2.13575]	-0.180162 (0.03992) [-4.51293]	-0.072523 (0.02429) [-2.98552]
<b>Transition Matrix Parameters</b>					
<b>Variable</b>	Coefficient	Std. Error	z-Statistic	Prob.	
<b>P11-C</b>	3.078594	0.511605	6.017521	0.0000	
<b>P21-C</b>	19.13593	6928.072	0.002762	0.9978	
Determinant resid covariance		1.745913			
Log likelihood		-655.0018			
Akaike info criterion		15.09477			
Schwarz criterion		16.76152			
Number of coefficients		62			

Note: Coefficients are reported along with standard errors and t-statistics in parentheses () and brackets [], respectively.

Source: Authors' computation using EViews 14.

There is a negative relationship between crude oil shocks and the current account balance in both regimes: -0.001207 in regime one and -0.026770 in regime two. These findings indicate that South Africa's economy is more susceptible to crude oil price shocks during periods of recession, as evidenced by the larger negative impact on the current account balance in regime two compared to regime one. This underscores the need for South Africa to build a more resilient and diverse economy to mitigate the adverse effects of external shocks, such as oil price fluctuations. By strengthening other sectors and reducing its dependency on oil, the country can better withstand economic downturns and enhance its overall economic stability.

**RGDP:** The lagged RGDP of 0.9389 indicates strong economic growth, while the lagged INF of -0.3353 suggests that higher previous inflation may dampen this growth. EXR lagged at 0.1434 indicates a positive effect, indicating that exchange rate changes can boost economic output. Additionally, the lagged IR of 0.2249 indicates that previous interest rates may positively

impact RGDP. Conversely, the negative coefficient in the lagged CAB suggests that a higher previous current account balance may be associated with lower RGDP, possibly due to resource allocation issues.

**INF:** The RGDP (-0.0136) indicates a slight negative correlation, suggesting that stronger economic growth does not significantly affect inflationary pressure. The lagged INF (0.9688) reflects stable inflation over time, while the lagged EXR (-0.0062) shows that exchange rate fluctuations have a minimal impact on inflation. Additionally, the lagged IR (-0.0057) indicates that interest rates have a negligible influence on inflation. Finally, the lagged CAB (0.0016) suggests a small positive impact, indicating a weak relationship.

**EXR:** Lagged RGDP (-0.0084) indicates a minimal influence of past GDP on current exchange rates. Lagged INF (-0.0329) shows a slight negative impact, suggesting that inflation may affect the exchange rate. Lagged EXR (0.8904) has a strong positive coefficient, indicating that past exchange rates significantly influence current exchange rates. The lagged IR (-0.0443) indicates that higher interest rates lead to depreciation of the exchange rate. Finally, the Lagged CAB (-0.0039) indicates a minimal influence of the current account balance on the exchange rate.

**IR:** The lag in RGDP (-0.2376) suggests that economic growth may lead to lower interest rates, potentially due to increased investor confidence. The negative relationship with Lagged INF (-0.1775) indicates that inflation could increase interest rates, although this impact is not significant. The lagged EXR (0.2925) shows that past exchange rate levels can significantly affect current interest rates. Lagged IR (0.9106) indicates strong persistence, meaning that past interest rates heavily influence current rates. Finally, a lagged CAB (0.0276) indicates a minimal effect on current interest rates.

**CAB:** Lagged RGDP (0.1376) indicates that higher economic output is associated with an improved current account balance. In contrast, lagged INF (-0.2868) shows that increased inflation negatively impacts the current account, likely due to diminished competitiveness. The small positive effect of lagged EXR (0.0904) suggests a relationship with exchange rates. Lagged IR (0.0254) has a minimal impact on the current account balance. Finally, lagged CAB (0.9709) demonstrates extremely high persistence, indicating strong continuity in current account balances over time.

This analysis offers a detailed examination of the interactions among various macroeconomic variables in South Africa, particularly in relation to crude oil price shocks. The significant persistence observed in variables such as RGDP, INF, and CAB indicates that shocks to the system can have enduring effects. In responding to external shocks, such as fluctuations in crude oil prices, policymakers must consider these interdependencies.

These values offer insights into how sensitive each macroeconomic variable is to fluctuations in crude oil prices across different economic regimes. In the first regime, the positive SIGMA-RGDP indicates that GDP growth is relatively stable and less influenced by oil price shocks. The low SIGMA-INF shows that inflation remains well-contained, while the high SIGMA-EXR demonstrates considerable volatility in the exchange rate. The negative SIGMA-IR suggests that interest rates tend to decline in response to oil price shocks, which could stimulate economic activity. Lastly, the negative SIGMA-CAB indicates that the current account balance worsens during oil price shocks, underscoring their impact on trade balances. Overall, these Sigma values provide a comprehensive overview of the macroeconomic effects of crude oil shocks in South Africa.

The P11-C coefficient is 3.078594, with a p-value of 0.0000, indicating a statistically significant positive response to crude oil price shocks. In contrast, the P21-C coefficient is 19.13593, accompanied by a p-value of 0.9978, suggesting no statistical significance. These results imply that during periods of economic expansion, the economy is better equipped to absorb and respond positively to fluctuations in crude oil prices. However, during recessions, the negative impact of oil price shocks is more pronounced and can have lasting effects on macroeconomic variables. The high p-value in this context points to uncertainty regarding this effect. Moreover, the findings suggest a low probability of transitioning from regime one to regime two, while the likelihood of remaining in regime two is high. This aligns with the notion that once an economy enters a recessionary phase; it can be difficult to recover quickly. Additionally, the high p-value for transitions from regime two to regime one indicates that such shifts are not statistically significant, reinforcing the idea that recovering from a recession poses substantial challenges. Overall, these findings underscore the importance of understanding different economic regimes and their implications for policy-making in response to crude oil price shocks.

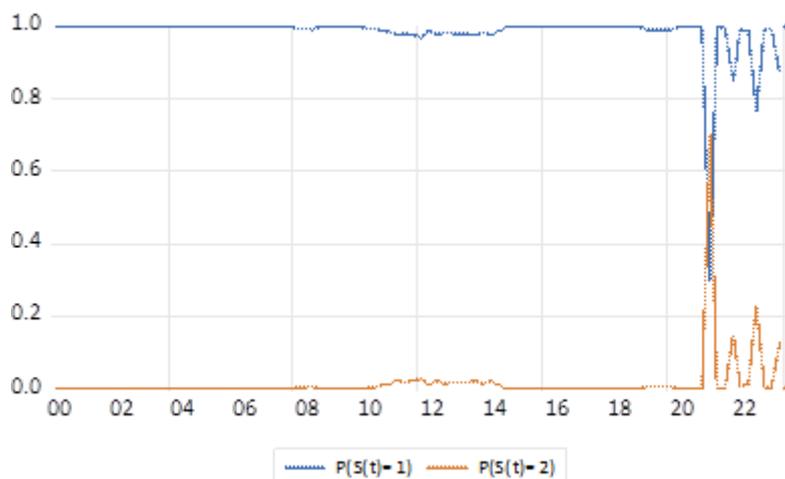
The determinant of residual covariance is 1.745913, the log likelihood is -655.0018, the Akaike Information Criterion (AIC) is 15.09477, and the Schwarz Criterion (SC) is 16.76152. These statistics suggest that the model fits the data well, as indicated by the relatively high determinant residual covariance and the low log likelihood. Additionally, both the AIC and SC fall within acceptable ranges, reinforcing the conclusion that the model is well-suited to analyzing the macroeconomic effects of crude oil shocks in South Africa.

#### 4.4. Diagnostic Test Results

##### 4.4.1. Probability Plot

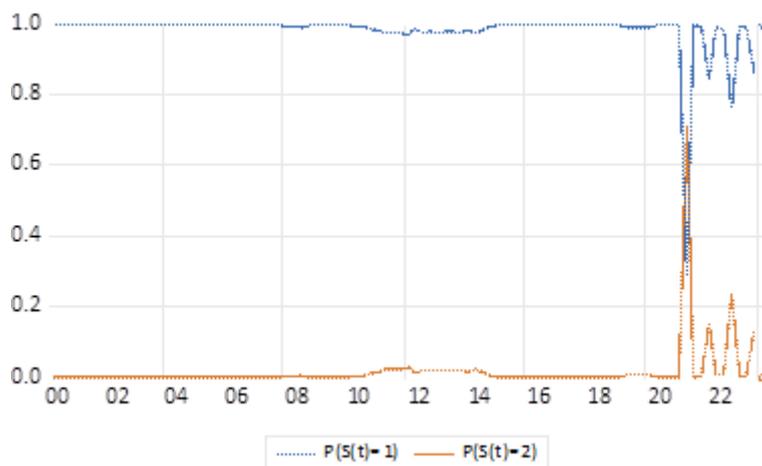
The macroeconomic effects of crude oil shocks in South Africa provide interesting insights into the country's economic performance. These shocks can be better understood by examining the probability plot of their impact. The information can be used by policymakers to mitigate the negative effects of oil price fluctuations on the South African economy.

**Figure 1: Filtered Regime Probabilities in the MSI-VAR Model**



In Figure 1, the regime probabilities show that South Africa is primarily in regime one, with a high probability of 0.982298. This indicates that the economy is generally experiencing robust growth and is well-prepared to withstand crude oil price shocks. However, there remains a small probability of 0.017702 for regime two, suggesting the possibility of a recession where oil price shocks could negatively affect macroeconomic variables. While South Africa's economy is expected to remain in regime one, reflecting its resilience to crude oil shocks, the small chance of regime two underscores potential vulnerabilities. Policymakers and economists should closely monitor these probabilities and be ready to respond to macroeconomic changes resulting from fluctuations in crude oil prices.

**Figure 2: Smoothed Regime Probabilities in the MSI-VAR Model**



The analysis of the Smoothed Regime Probabilities indicates that South Africa's economy predominantly operates in regime one, with a probability of 0.981959, as illustrated in Figure 2. This suggests that the economy is generally in a state of high growth, which protects against crude oil price shocks. A small chance of 0.018041 remains for regime two, suggesting that the impact of oil price shocks on macroeconomic variables in South Africa can be greater during recessionary periods. Understanding these regime probabilities can help policymakers better prepare for external shocks and mitigate their effects.

#### 4.4.2. Transition Probability

Transition Probability Analysis is a valuable tool for understanding how crude oil shocks impact the South African economy. By examining the transition probabilities between different economic states in response to fluctuations in oil prices, we can gain insights into how these shocks influence key macroeconomic variables such as GDP growth, inflation, exchange rates, interest rates, and the current account balance. This method helps to comprehend the repercussions of external shocks on the South African economy and to develop effective policy measures to mitigate their adverse effects.

**Table 4: Transition Probability and Expected Duration**

South Africa	Regime 1	Regime 2
Regime 1	0.956001	0.043999
Regime 2	1.000000	4.89E-09
Durations	22.72784	1.000000

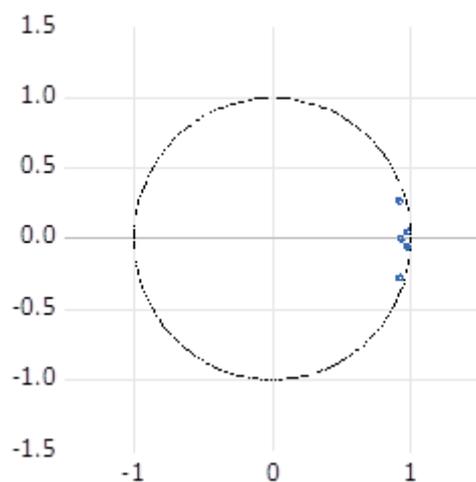
Source: Authors' Estimation using EViews 14

The Markov switching model indicates that South Africa's economy is predominantly in regime one, which is characterized by high growth and resilience to crude oil price shocks. This conclusion is supported by a high probability of remaining in regime one ( $P(1|1) = 0.956001$ ) and a relatively long expected duration of this regime (22.72784). In contrast, regime two, which signifies a recession, is less likely to occur and has a shorter expected duration (1.000000). This suggests that the economy is well-equipped to withstand and recover from oil price shocks, underscoring its adaptive capacity in the face of external economic challenges.

#### 4.4.3. Inverse Roots

This study analyzes the inverse roots of the AR characteristic polynomial to gain insights into the system's dynamics and stability in response to shocks.

**Figure 3: Inverse Roots of AR Characteristic Polynomial**



The results indicate that all inverse roots are located within the unit circle, demonstrating that the system is stable in both regime one and regime two. This analysis underscores the importance of comprehending the system's underlying dynamics to effectively mitigate the impact of external shocks on macroeconomic variables.

### 5. DISCUSSIONS

During the first regime, there was a negative relationship between crude oil shocks and real GDP growth in South Africa. This finding aligns with studies by Omojolaibi and Egwaikhide (2013) and Cheng et al. (2019), which indicated that increases in oil prices inversely affect GDP growth in China. However, in the second regime, the relationship shifts to positive, suggesting that rising oil prices contribute to increased GDP growth in South Africa. This observation is consistent with research by Omojolaibi and Egwaikhide (2013), Zulfargarov and Neuenkich (2020), and Lizein et al. (2024), which noted the positive impact of rising oil prices on GDP growth in the US, Japan, Azerbaijan, and Indonesia, respectively. The MSI-VAR model provides a more nuanced understanding of the relationship between crude oil shocks and GDP growth, capturing its evolving nature over time through multiple structural breaks, in contrast to traditional VAR models.

There is a negative relationship between crude oil shocks and inflation in South Africa across both economic regimes. This aligns with the findings of Al-Mulali et al. (2011), who also reported a negative impact of oil price shocks on inflation in Qatar. These results indicate that oil price shocks affect inflation similarly in various countries, irrespective of their economic conditions and policies. The findings of this study offer valuable insights for South African policymakers, emphasizing the need to monitor and manage the effects of crude oil price fluctuations on inflation rates. By comprehending this relationship, policymakers can take appropriate measures to mitigate the potential adverse effects of oil price shocks on the economy.

There is a positive relationship between crude oil shocks and exchange rates in regime one in South Africa. This finding aligns with the work of Kiliçarslan and Dumrul (2017) in Turkey, who employed the SVAR method and discovered that rising crude oil prices were associated with higher real exchange rates. Conversely, in regime two, the relationship is negative. This outcome corresponds with the findings of Lizein et al. (2024), who also used SVAR and identified a positive link between oil price shocks and exchange rates in Indonesia. It appears that the impact of crude oil shocks on exchange rates varies depending on the economic regime and the country. The MSI-VAR approach provides a more comprehensive understanding of the relationship between oil price shocks and exchange rates in South Africa, facilitating a deeper analysis of the various economic regimes. By acknowledging these differing impacts, policymakers can tailor their responses to effectively mitigate the potential negative effects of oil price fluctuations on exchange rates.

There is a positive correlation between crude oil shocks (OIL) and interest rates (IR) in regime one. This aligns with the findings of Lizein et al. (2024), who utilized SVAR analysis to identify a similar positive relationship between oil price shocks and interest rates in Indonesia. Conversely, in regime two, the relationship turns negative. This unexpected outcome indicates that different factors may influence interest rates during periods of oil shocks in regime two.

There is a negative relationship between crude oil shocks and the current account balance in both regime one and regime two in South Africa. It echoes the findings of Yildirim and Arifli (2021), who used the VAR model to show that negative oil price shocks decrease trade balances in Azerbaijan. The trade balances of oil-dependent countries, including South Africa, are significantly affected by fluctuations in oil prices. As a net importer of oil, South Africa may face challenges maintaining a positive current account balance when confronted with negative oil price shocks. To mitigate the country's vulnerability to oil price fluctuations, policymakers should diversify its energy sources. Additionally, the MSI-VAR model provides more robust estimates of the effects of oil price shocks on trade balances, enabling a more accurate assessment of the potential impact on South Africa's economy compared to the VAR approach used by Yildirim and Arifli (2021).

## 6. CONCLUSION AND IMPLICATIONS

The study aimed to analyze the macroeconomic effects of crude oil shocks in South Africa using a Markov Switching Intercepts VAR (MSI-VAR) approach, covering the period from 2000Q1 to 2023Q4. PP and ADF tests confirmed the presence of unit roots, indicating non-stationarity of the variables. The MSI-VAR results revealed a minimal negative correlation between crude oil shocks and real GDP growth in regime one, while a positive relationship emerged in regime two, suggesting that oil shocks can boost economic output during recessions. In addition, the negative correlation between crude oil shocks and inflation in South Africa was stronger during recessionary periods, suggesting that these shocks have a greater impact. This highlights the importance of understanding different economic regimes. The relationship between crude oil shocks and the exchange rate also varied depending on economic conditions, displaying positive correlations during periods of economic growth and negative correlations during recessions. Additionally, the connection between crude oil shocks and interest rates varied across regimes, with high-growth periods enabling effective mitigation, while recessions intensified their impact. Under both regimes, crude oil shocks negatively correlated with the current account balance, highlighting the vulnerability of the South African economy. Overall, the findings suggest that South Africa's economy is highly sensitive to fluctuations in crude oil prices, with varying effects depending on the prevailing economic climate.

The findings suggest that the South African government should take measures to diversify the economy and lessen its dependence on crude oil imports. This strategy could help stabilize the current account balance and reduce the economy's vulnerability to external shocks. Furthermore, the government should prioritize maintaining a stable exchange rate through careful monetary and fiscal policies to lessen the effects of crude oil shocks on interest rates and overall economic activity. Ultimately, a proactive approach to addressing these vulnerabilities is crucial for ensuring long-term economic sustainability in South Africa.

## REFERENCES

- Alawadhi, S. A., & Longe, A. E. (2024). Oil Price Fluctuation and their Impact on the Macroeconomic Variables: The Case of Kuwait. *International Journal of Energy Economics and Policy*, 14(3), 375–386. <https://doi.org/10.32479/ijeep.15713>
- Al-mulali, U., Sab, C., & Binti, C. N. (2011). The impact of oil prices on the real exchange rate of the dirham: a case study of the United Arab Emirates (UAE). *OPEC Energy Review*, 35(4), 384-399. <https://doi.org/10.1111/j.1753-0237.2011.00198.x>
- Aloui, C., Hkiri, B., Hammoudeh, S., & Shahbaz, M. (2018). A Multiple and Partial Wavelet Analysis of the Oil Price, Inflation, Exchange Rate, and Economic Growth Nexus in Saudi Arabia. *Emerging Markets Finance and Trade*, 54(4), 935–956. <https://doi.org/10.1080/1540496X.2017.1423469>

- Azad N. F., & Serletis A. (2020). Oil price shocks in major emerging economies. *Energy Policy*, 43, SSRN Electronic Journal. <https://doi.org/10.2139/ssrn.3577378>
- Basnet, H. C., Kamal P., & Upadhyaya, K.P. (2015). Impact of oil price shocks on output, inflation and the real exchange rate: Evidence from selected ASEAN countries. *Applied Economics*, 47, 3078–91. <https://doi.org/10.1080/00036846.2015.1011322>
- Besso C. R., Feubi P., & Erick, P. (2017). Oil price shock and economic growth: Experience of CEMAC countries. *Theoretical and Practical Research in Economic Fields*, 8(1), 5–18. [https://doi.org/10.14505/tpref.v8.1\(15\).01](https://doi.org/10.14505/tpref.v8.1(15).01)
- Cheng D., Shi X., Yu J., & Zhang D. (2019). How does the Chinese economy react to uncertainty in international crude oil prices? *International Review of Economics & Finance*. 64, 147–164. <https://doi.org/10.1016/j.iref.2019.05.008>
- Chisadza, C., Dlamini, J., Gupta, R., & Modise, M. P. (2016). The impact of oil shocks on the South African economy. *Energy Sources, Part B: Economics, Planning, and Policy*, 11(8), 739-745. <https://doi.org/10.1080/15567249.2013.781248>
- Fasanya,I., & Makanda, S. (2024). Disentangled oil shocks and macroeconomic policy uncertainty in South Africa. *Resources Policy*, 95, <https://doi.org/10.1016/j.resourpol.2024.105195>
- Hollander, H., Gupta, R., & Wohar, M. E. (2018). The impact of oil shocks in a small open economy New-Keynesian dynamic stochastic general equilibrium model for an oil-importing country: The case of South Africa. *Emerging Markets Finance and Trade*, 55(7), 1593-1618. <https://doi.org/10.1080/1540496X.2018.1474346>
- Jiang, W., & Liu, Y. (2021). The asymmetric effect of crude oil prices on stock prices in major international financial markets. *The North American Journal of Economics and Finance*, 56. <https://doi.org/10.1016/j.najef.2020.101357>
- Khan A., Khan M. Y., & Khan A. Q. (2020). How do oil and natural gas prices affect U.S. industrial production? Utilizing wavelet nonlinear denoised based quantile analysis. *Energy Strategy Reviews*, 32. <https://doi.org/10.1016/j.esr.2020.100550>
- Kiliçarslan Z., & Dumrul, Y. 2017 Macroeconomic Impacts of Oil Price Shocks: an Empirical Analysis Based on the Svar Models. *Revista Economica*, 69(5), 55-72.
- Kırca, M, Canbay, M., & Piralı, K. (2020). Is the relationship between oil-gas prices index and economic growth in Turkey permanent? *Resources Policy*, 69, <https://doi.org/10.1016/j.resourpol.2020.101838>
- Lizein, B., Triansyah, F.A., Acheampong, K., Ahmad, S.Y, & Mosavi, H. (2024). Fluctuations oil prices in the world and their impact on Indonesian macroeconomics. *IOP Conference Series: Earth and Environmental Science*. 1379 012030. <https://doi.org/10.1088/1755-1315/1379/1/012030>
- Magazzino, C., Mutascu, M., & Mele, M. (2021). Energy consumption and economic growth in Italy: A wavelet analysis. *Energy Reports*, 7, 1520-1528. <https://doi.org/10.1016/j.egy.2021.03.005>
- Marna, K., Essama-Nssah, B., Vijdan, K., Go, D. S., Robinson, S., & Thierfelder, K. (2007). *Economy-wide and Distributional Impacts of an Oil Price Shock on the South African Economy*. World Bank Policy Research Working Paper No. 4354. <http://hdl.handle.net/10986/7350>
- Miamo, C. W., & Achuo, E. D. (2021). Can the resource curse be avoided? An empirical examination of the nexus between crude oil price and economic growth. *SN Business & Economics*. 2(1):5. <https://doi.org/10.1007/s43546-021-00179-x>
- Nazlioglu, S., Gormus, A., & Soytaş, U. (2019). Oil prices and monetary policy in emerging markets: structural shifts in causal linkages. *Emerging Markets Finance and Trade*, 55(1), 105-117. <https://doi.org/10.1080/1540496X.2018.1434072>
- Omojolaibi J. A., & Egwaikhide F. O. (2013) A Panel Analysis of Oil Price Dynamics, Fiscal Stance and Macroeconomic Effects: The Case of Some Selected African Countries. *CBN Economic and Financial Review*, 51(1), 61-91. <https://dc.cbn.gov.ng/efr/vol51/iss1/4/>
- Rafiq S., Salim R., & Bloch H. (2009). Impact of crude oil price volatility on economic activities: an empirical investigation in the Thai economy. *Resources Policy*, 34, 121–132. <https://doi.org/10.1016/j.resourpol.2008.09.001>
- Saddiqui S. A., Jawad M., Naz M., & Niazi G. S. K. (2018). Exchange rate, fiscal policy and international oil prices impact on oil prices in Pakistan: a volatility and granger causality analysis. *Review of Innovation and Competitiveness*. 4(1), 27–46. <https://doi.org/10.32728/ric.2018.41/2>
- Sheng, X., Gupta R., & Ji, Q. (2020). The impacts of structural oil shocks on macroeconomic uncertainty: Evidence from a large panel of 45 countries. *Energy Economics*, 91. <https://doi.org/10.1016/j.eneco.2020.104940>
- Van Eyden, R., Difeto, M., Gupta, R., & Wohar, M.E. (2019). Oil price volatility and economic growth: Evidence from advanced economies using more than a century’s data. *Applied Energy*, 233–234, 612-621. <https://doi.org/10.1016/j.apenergy.2018.10.049>
- Yildirim, Z., & Arifli, A. (2021). Oil price shocks, exchange rate and macroeconomic fluctuations in a small oil-exporting economy. *Energy*, 219, 119527. <https://doi.org/10.1016/j.energy.2020.119527>
- Zulfıgarov, F., & Neuenkirch, M. (2020). The impact of oil price changes on selected macroeconomic indicators in Azerbaijan. *Economic Systems*, 44(4), 100814. <https://doi.org/10.1016/j.ecosys.2020.100814>

**APPENDIX 1: Descriptive Statistics of Data**

	<b>RGDP</b>	<b>INF</b>	<b>EXR</b>	<b>IR</b>	<b>CAB</b>	<b>OIL</b>
Mean	2.330208	112.8761	85.69135	10.79323	-2.016895	66.17688
Median	2.500000	108.0200	82.88500	10.25000	-2.793197	62.64000
Maximum	5.600000	174.9900	108.9900	17.00000	4.123380	121.3100
Minimum	-6.300000	58.14000	64.68000	7.000000	-5.836930	19.40000
Std. Dev.	2.159050	37.24312	11.99395	2.546241	2.795811	28.96720
Skewness	-1.183971	0.188697	0.282692	0.670604	0.535743	0.247786
Kurtosis	5.724747	1.604611	1.830739	2.657945	2.188086	1.978794
Jarque-Bera	52.12560	8.358145	6.747326	7.663365	7.229146	5.153816
Probability	0.000000	0.015313	0.034264	0.021673	0.026928	0.076009
Sum	223.7000	10836.11	8226.370	1036.150	-193.6219	6352.980
Sum Sq.	964.1100	1354907.	718595.0	11799.32	1133.088	500134.7
Sum Sq. Dev.	442.8424	131769.8	13666.21	615.9175	742.5732	79714.37
Observations	96	96	96	96	96	96

**APPENDIX 2: Dataset**

<b>Year</b>	<b>RGDP</b>	<b>INF</b>	<b>EXR</b>	<b>IR</b>	<b>CAB</b>	<b>OIL</b>
2000 Q1	4,2	58,14	103,77	14,5	-0,13765	26,84
2000 Q2	3,8	59,54	100,1	14,5	-0,03384	26,68
2000 Q3	3,5	60,66	101,15	14,5	0,06997	30,6
2000 Q4	3,1	61,26	96,55	14,5	0,17378	29,72
2001 Q1	2,7	62,46	93,55	14,5	0,27759	25,88
2001 Q2	3	63,36	94,84	14,25	0,426205	27,27
2001 Q3	3,2	63,56	85,76	13,33	0,57482	25,33
2001 Q4	3,5	63,9	76,89	13	0,723435	19,4
2002 Q1	3,7	66,06	69,32	14,33	0,87961	21,05
2002 Q2	3,5	68,32	76,25	15,33	0,434135	25,06
2002 Q3	3,3	70,37	75,36	16,33	-0,00378	26,94
2002 Q4	3,1	72,52	83,04	17	-0,441695	26,76
2003 Q1	2,9	73,59	93,09	17	-0,87961	31,61
2003 Q2	3,3	73,98	96,92	16,5	-1,361153	26,08
2003 Q3	3,8	73,45	100,52	14,5	-1,842695	28,5
2003 Q4	4,2	72,04	104,2	11,83	-2,324237	29,35
2004 Q1	4,6	72,3	99,42	11,5	-2,80578	31,92
2004 Q2	4,8	72,71	103,97	11,5	-2,88171	35,3
2004 Q3	4,9	72,8	106,44	11,17	-2,95764	41,13
2004 Q4	5,1	73,23	108,59	11	-3,03357	44,29
2005 Q1	5,3	73,69	108,34	11	-3,1095	47,45
2005 Q2	5,4	74,06	102,85	10,5	-3,450783	51,04
2005 Q3	5,4	74,55	102,93	10,5	-3,792065	61,64
2005 Q4	5,5	74,73	103,81	10,5	-4,133348	56,97
2006 Q1	5,6	75,2	108,99	10,5	-4,47463	61,45
2006 Q2	5,5	75,94	101,97	11,4	-4,708087	69,44
2006 Q3	5,5	77,35	92,47	11,33	-4,941545	69,53
2006 Q4	5,5	78,17	90,67	12,17	-5,175003	59,55
2007 Q1	5,4	79,07	91,25	12,5	-5,40846	57,86
2007 Q2	4,9	80,51	91,87	12,67	-5,485643	69,03
2007 Q3	4,3	82,21	91,16	13,33	-5,562825	75,84
2007 Q4	3,8	83,83	93,78	14,17	-5,640008	89,07
2008 Q1	3,2	86,15	83,77	14,5	-5,71719	97,71
2008 Q2	2	88,49	80,44	15,17	-4,95219	121,31
2008 Q3	0,9	91,48	83,59	15,5	-4,18713	115,86
2008 Q4	-0,3	92,3	73,59	13,9	-3,4221	56,21
2009 Q1	-1,5	93,77	75,1	14	-2,65707	44,49
2009 Q2	-0,4	95,7	87,94	11,67	-2,35391	58,74
2009 Q3	0,8	97,24	92,56	10,67	-2,05075	68,41
2009 Q4	1,9	97,58	94,28	10,5	-1,74759	74,71
2010 Q1	3	98,81	96,64	10,33	-1,44443	76,31

2010 Q2	3,1	99,69	99,26	10	-1,638905	78,61
2010 Q3	3,1	100,51	100,88	9,83	-1,83338	76,75
2010 Q4	3,2	100,98	103,22	9,17	-2,027855	86,48
2011 Q1	3,2	102,45	101,34	9	-2,22233	104,57
2011 Q2	2,8	104,32	102,13	9	-2,95016	117,27
2011 Q3	2,6	105,97	98,68	9	-3,67799	113,16
2011 Q4	2,4	107,26	90,91	9	-4,40582	109,76
2012 Q1	2,4	108,78	95,54	9	-5,13365	118,5
2012 Q2	2,5	110,48	93,34	9	-5,30947	108,63
2012 Q3	2,5	111,48	92,51	8,5	-5,48529	109,6
2012 Q4	2,5	113,3	88,29	8,5	-5,66111	110,47
2013 Q1	2,5	115,17	86,58	8,5	-5,83693	112,7
2013 Q2	2,2	116,64	83,08	8,5	-5,685668	102,86
2013 Q3	2	118,46	80,11	8,5	-5,534405	110,32
2013 Q4	1,7	119,45	78,66	8,5	-5,383143	109,29
2014 Q1	1,4	121,86	74,99	9	-5,23188	108,24
2014 Q2	1,4	124,38	77,76	9	-5,10093	109,91
2014 Q3	1,4	126,02	77,71	9,25	-4,96998	102,16
2014 Q4	1,3	126,26	77,92	9,25	-4,83903	76,66
2015 Q1	1,3	127,08	78,29	9,25	-4,70808	54,14
2015 Q2	1,2	130,01	77,67	9,25	-4,249995	61,78
2015 Q3	1	131,71	74,67	9,5	-3,79191	50,37
2015 Q4	0,8	132,36	70,34	9,67	-3,333825	43,7
2016 Q1	0,7	135,35	64,68	10,33	-2,87574	33,8
2016 Q2	0,8	138,45	67,69	10,5	-2,805575	45,48
2016 Q3	1	140,16	73,41	10,5	-2,73541	45,72
2016 Q4	1,1	141,45	76,91	10,5	-2,665245	49,31
2017 Q1	1,2	144,14	82,05	10,5	-2,59508	53,72
2017 Q2	1,3	145,67	80,88	10,25	-2,780818	49,74
2017 Q3	1,4	146,55	78,92	10,25	-2,966555	52,02
2017 Q4	1,4	147,84	76,74	10,25	-3,152293	61,5
2018 Q1	1,5	149,83	85,03	10,17	-3,33803	66,82
2018 Q2	1,2	151,83	82,73	10	-3,219525	74,45
2018 Q3	0,9	153,94	77,36	10	-3,10102	75,35
2018 Q4	0,6	155,05	78,19	10,17	-2,982515	67,49
2019 Q1	0,3	156,05	79,11	10,25	-2,86401	63,15
2019 Q2	-1,4	158,69	78,36	10,25	-1,585505	68,96
2019 Q3	-3	160,15	77,81	10	0,307	62,13
2019 Q4	-4,6	160,86	77,8	10	0,971505	63,33
2020 Q1	-6,3	162,79	75,88	9,42	2,25001	50,61
2020 Q2	-3,5	162,38	66,31	7,42	2,718353	29,37
2020 Q3	-0,7	165,02	68,76	7	3,186695	42,99
2020 Q4	2,1	165,96	73,26	7	3,655038	44,12
2021 Q1	4,9	167,83	75,57	7	4,12338	60,73
2021 Q2	2,1	170,41	80,37	7	4,0346	68,7
2021 Q3	3,2	173,17	78,78	7	3,23097	73,47
2021 Q4	4,3	174,99	75,91	7,17	2,90457	79,76
2022 Q1	3	173,901	74,91	7,1	2,1297	98,64
2022 Q2	2,1	167,091	73,13	8,89	2,02341	113,39
2022 Q3	3,1	166,9081	73,34	8,9	2,09834	100,88
2022 Q4	2,2	167,093	72,09	7	1,90376	88,88
2023 Q1	2,3	166,0929	69,01	8,2	1,99286	81,22
2023 Q2	3,1	160,6781	69,09	7,9	2,9024	78,47
2023 Q3	1,3	169,0921	70,01	9,09	2,09139	86,42
2023Q4	1,7	156,99	70,67	10,09	2,09123	84,1

## BLOCKCHAIN IN FINANCE: A SYSTEMATIC LITERATURE REVIEW

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Bulut Karadag<sup>1</sup>, Abdul Halim Zaim<sup>2</sup>, Akhan Akbulut<sup>3</sup>

<sup>1</sup>Istanbul Commerce University, Computer Engineering, Kucukyali, Istanbul, Turkiye.

[bulutkaradag@istanbulticaret.edu.tr](mailto:bulutkaradag@istanbulticaret.edu.tr), ORCID: 0000-0001-9976-8121

<sup>2</sup>Istanbul Technical University, Computer Engineering, Ayazaga, Istanbul, Turkiye.

[azaim@itu.edu.tr](mailto:azaim@itu.edu.tr), ORCID: 0000-0002-0233-064X

<sup>3</sup>Istanbul Kultur University, Computer Engineering, Atakoy, Istanbul, Turkiye.

[a.akbulut@iku.edu.tr](mailto:a.akbulut@iku.edu.tr), ORCID: 0000-0001-9789-5012

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### ABSTRACT

**Purpose-** This study aims to conduct a systematic literature review (SLR) on the use of blockchain technology in finance.

**Methodology-** The study analyzes 54 research articles, out of which 32 were relevant to the SLR questions. Nine research questions were formulated and investigated through the chosen articles. These questions can be categorized into three main areas: technical aspects, benefits and challenges, and current/future application areas.

**Findings-** The research reveals the potential of blockchain technology to improve efficiency, reduce costs, and enhance transparency and security in the financial sector. The study identifies technical features of blockchain along with its current and potential applications in finance. Benefits and challenges associated with blockchain technology are explored. Regulatory constraints, scalability concerns, and interoperability issues are highlighted as barriers that need to be addressed.

**Conclusion-** This SLR offers valuable insights into the current state of research on blockchain in finance. It provides a comprehensive analysis of the technology's infrastructure, technology, advantages, and limitations. The findings shed light on potential future applications and pave the way for further research in this domain. This study is particularly beneficial for individuals interested in pursuing blockchain technology in finance.

**Keywords:** Systematic literature review, blockchain, finance, blockchain Infrastructure, smart contract

**JEL Codes:** E42, D82, D83

## 1. INTRODUCTION

The financial sector has undergone tremendous transformation as a result of the broad adoption of digital technologies, especially the emergence of blockchain technology. According to Nakamoto, the blockchain is a decentralized digital database that enables safe and transparent transactions without the use of intermediaries. Blockchain technology has the potential to improve efficiency, save costs, boost transparency and improve security in the financial sector. Blockchain has been the focus of significant study and development over the past few years and its potential financial applications have received a lot of attention. The potential uses of blockchain in finance are numerous and range from reducing fraud in financial transactions to enabling new forms of digital currencies and decentralized financial systems (Werbach, K., 2018).

Although blockchain adoption in the financial sector is still in its early stages, interest in its potential uses is growing. The application of blockchain in the financial services sector is being investigated for a number of goals, such as lowering financial transaction fraud, enabling new types of digital currencies and developing decentralized financial systems. Additionally, blockchain has the ability to enhance a number of financial procedures, such as banking operations, digital identity management and supply chain management. Despite all the excitement surrounding blockchain technology in finance, there are still issues that need to be resolved. For instance, legal concerns, interoperability and scalability limitations, as well as a lack of standards, are all challenges that must be overcome for blockchain technology to be successfully implemented in the financial sector.

This study conducts a systematic literature review of the existing research on blockchain in finance, with a focus on its potential uses, benefits and challenges. The literature review offers a thorough summary of the state of research on

blockchain in finance at present and emphasizes the need for more study to fully fulfill this technology's potential. The report also sheds light on the potential advantages of blockchain for various financial processes and services, such as supply chain management, digital identity management, financial services and infrastructure (Kshetri, N., 2018).

The rest of the paper is organized as follows. Section 2 provides a review of the existing literature on blockchain in finance. Section 3 provides the research methodology of the study. Results are presented in section 4. Finally, Section 5 concludes the study and provides recommendations for future research.

## **2. RELATED WORK**

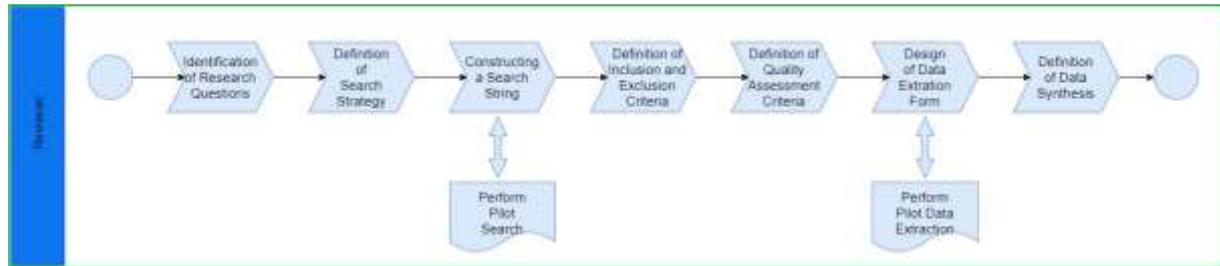
There are some reviews about the blockchain used in the financial ecosystem. For instance, R. Böhme et al. (Böhme, R., Christin, N., Edelman, B., & Moore, T., 2015) provide a detail review of the blockchain in finance. This study provides an overview of the current state of blockchain technology in the financial industry and discusses potential use cases, challenges and future directions for research. V. Gattesch et al. (Gatteschi, V., Lamberti, F., Demartini, C., Pranteda, C., & Santamaria, V., 2018) conducted a study that examines the potential benefits and challenges of using blockchain technology in the insurance industry and discusses possible use cases and future research directions. This study conducted by D. K. Wardhani et al. (Wardhani, D. K., Sawarjuwono, T., & Budisusetyo, S., 2018) in order to provides an overview of the potential benefits and challenges of using blockchain technology in capital markets and discusses current and future use cases. Another study on blockchain technology in banking performed by M. U. Chowdhury et al. (Chowdhury, M. U., Suchana, K., Alam, S. M. E., & Khan, M. M., 2021) that provides a value-based analysis of blockchain technology in the banking sector, examining how it could be used to create new value for customers and banks and discussing the challenges that need to be overcome for successful implementation. M. Mainelli et al. (Mainelli, M., & Milne, A., 2016) examined the potential impact of blockchain technology on the securities transaction lifecycle, including the benefits and challenges that it could bring, as well as discussing its potential to reduce costs and improve efficiency. In this study, M. Javaid et al. (Javaid, M., Haleem, A., Singh, R. P., Suman, R., & Khan, S., (2022) provided a comprehensive overview of the current and potential future applications of blockchain technology in the financial services industry, including use cases in payments, securities trading and insurance, as well as discussing the challenges and opportunities that it presents. S. Grima et al. (Grima, S., Spiteri, J., & Románova, I., 2020) examined the potential effects of blockchain technology on the insurance sector, including the advantages and drawbacks it might present as well as how it might boost productivity, boost transparency and cut costs. Another study conducted by S. E. Chang et al. (Chang, S. E., Luo, H. L., & Chen, Y., 2020) provided an overview of the use of blockchain technology in trade finance and the opportunities it presents. It also examines the challenges that need to be overcome for successful implementation and the future possibilities of the technology. In research she conducted, M. Morini (Morini, M., 2016) gives a broad overview of the potential applications of blockchain technology in the capital markets, including both the advantages such as in creased effectiveness and lower costs and the obstacles that must be overcome before adoption can take place. Another study examined by I. Amsyar et al. (Amsyar, I., Christopher, E., Dithi, A., Khan, A. N., & Maulana, S., 2020) provided a comprehensive review of the existing literature on blockchain and cryptocurrencies, examining the benefits and challenges of the technology, as well as the current state of research and future directions. In another blockchain study on banking P. Garg et al. (Garg, P., Gupta, B., Chauhan, A. K., Sivarajah, U., Gupta, S., & Modgil, S., 2021) examined the feasibility of blockchain technology in the banking industry, including the benefits that it could bring, such as improved efficiency and increased security, as well as discussing its potential to improve transparency. A-E. Panait et al. (Panait, A.-E., Olimid, R. F., & Stefanescu, A., 2020) studied the possible effects of blockchain technology on digital identity management, as well as the difficulties it might pose in terms of increased privacy and security.

## **3. RESEARCH METHODOLOGY**

The related study covers current trends and technologies used in the use of blockchain in finance. In addition, we aim to review the basic features of blockchain for finance studies to be developed using blockchain. Thus, this study can provide an accelerating support to both academic and project studies in this field in the future. By doing this, we are conducting a preliminary SLR study of the benefits and challenges of using blockchain.

Before conducting the SLR, we developed a review methodology based on studies from (Ali, M. S., Babar, M. A., Chen, L., & Stol, K.-J., 2010), (Kitchenham, B., & Charters, S., 2007) that were cited by field experts who emphasized that a protocol reduces bias among researchers and promotes repeatability. The review protocol is shown in Figure 1.

Figure 1: Systematic Literature Review Protocol



A list of research questions for the SLR is provided in Table 1. The SLR's scope, search techniques and search string are all described in Sections 3.2 to 3.2.3. The inclusion/exclusion criteria for the obtained literature are described in Section 3.2.4. and the quality evaluation criteria for the retrieved literature are included in Section 3.3.

### 3.1. Research Questions

We created a set of research questions that the SLR needs to answer. These inquiries came about from a developer's perspective. While conducting a blockchain study in finance, infrastructures (1), technology (2), benefits (3), consensus methods (4), permission types (5), future applications (6), most known use cases (7), smart contracts (8) and difficulties (9) were addressed as research questions.

Table 1: Research Questions

No	Research Question (RQ)
RQ1	Which blockchain infrastructures are used in finance?
RQ2	What technologies are used in finance with blockchain?
RQ3	What are the benefits of implementing blockchain in finance?
RQ4	Which consensus methods of blockchain are used in finance?
RQ5	What permission types of blockchain are used in finance?
RQ6	What are the potential future applications of blockchain technology in finance?
RQ7	What are the most common uses of blockchain technology in the financial industry?
RQ8	Which smart contracts programming languages of blockchain are used in finance?
RQ9	What are the challenges of implementing blockchain in finance?

### 3.2. Search Strategy

The literature search focuses on blockchain studies related to finance while excluding irrelevant studies. It needs a well-thought-out search technique to get high recall and precision levels. The review's search strategy is described in detail in this part, including the search string, search method and search scope.

#### 3.2.1. Search Scope

While conducting the research, the criteria for publication date and publication venue were taken into account. The literature review is conducted in January 2023 and the papers were chosen between January 2017 and January 2023. The following articles were searched according to the publication venue;

IEEE, Springer Nature, Elsevier, Mdpi, Wiley, Assoc Computing Machinery, British Blockchain Assoc, Emerald Group Publishing, Fac Law - Univ Zagreb, Federal Reserve Bank St Louis, Frontiers Media Sa, Higher Education Press, Incisive Media, Keai Publishing Ltd, Pageant Media Ltd, Springer Int Publ Ag, Slovensko Drustvo Informatika, Univ Illinois, Walter De Gruyter, World Scientific.

#### 3.2.2. Search Method

We performed an automated literature search for this systematic review. Automatic search is the process of searching via electronic databases for specific search terms. For each publication venue, mainly "ISI Web of Knowledge Web of Science" website was used and an automatic search was conducted.

#### 3.2.3. Search String

We used the following search string to find blockchain related articles in finance:

(*ALL=(Blockchain) AND (ALL=(Finance) OR ALL=(Fintech)) AND ALL=(infrastructure) AND (ALL=(Smart Contracts) OR ALL=(Permission Types) OR ALL=(Distributed Ledger) OR ALL=(Consensus))*)

Table 2 displays the search query results. The automatic search retrieved a total of 52 articles. Those who were unable to answer the SLR questions were removed and 34 articles were selected.

**Table 2: An overview of search results at two phases of the SLR process**

Source	Source After Automated Search	Search After Quality Assessment
IEEE	14	6
Springer Nature	6	6
Elsevier	4	4
Mdpi	4	3
Wiley	4	2
Assoc Computing Machinery	2	1
Asoc Economia Aplicadad	1	0
British Blockchain Assoc	1	1
Emerald Group Publishing	1	1
Fac Law - Univ Zagreb	1	1
Federal Reserve Bank St Louis	1	1
Frontiers Media Sa	1	1
Higher Education Press	1	1
Incisive Media	1	1
Iop Publishing Ltd	1	0
Keai Publishing Ltd	1	1
Now Publishers Inc	1	0
Pageant Media Ltd	1	1
Springer Int Publ Ag	1	1
Slovensko Drustvo Informatika	1	1
Taylor & Francis	1	0
Univ Illinois	1	1
Walter De Gruyter	1	1
World Scientific	1	1

### 3.2.4. Study Selection Criteria

The terms “Blockchain” and “Finance” provided many works output. We identified relevant studies using the study selection criteria given in Table 3. In this table, IC refers to the inclusion criteria.

**Table 3: Study Inclusion Criteria**

No.	Criteria
IC1	The study is not published in a language other than English
IC2	The study is published after 2010
IC3	The study must be related to finance using blockchain
IC4	The study must have full text (e.g., abstract-only papers are not considered)

### 3.3. Study Quality Assessment

The quality of the selected literature was evaluated in addition to the inclusion criteria. To evaluate whether any variables would skew the study’s findings, quality standards were developed. Table 4 lists the standards for quality. We used the summary quality checklist for quantitative and qualitative studies as recommended by (Kitchenham, B., & Charters, S., 2007) and (Gurbuz, H. G., & Tekinerdogan, B., 2018) for creating the criteria for evaluating the level of quality. More than a hundred articles were checked against the inclusion criteria and quality checklist, resulting in 34 articles to be reviewed in the SLR.

**Table 4: Quality Checklist**

No.	Question
Q1	Are the aims of the study clearly declared?
Q2	Are the scope and context of the study clearly defined?
Q3	Is the proposed solution clearly explained and validated by an empirical study?
Q4	Are the variables used in the study likely to be valid and reliable?
Q5	Is the research process documented adequately?
Q6	Are at least three questions answered?
Q7	Are the challenge findings presented?
Q8	Are the main findings stated clearly in terms of credibility, validity, and reliability?

### 3.4. Data Extraction

We extracted baseline data from the thirty-four studies using a standardized procedure called a data extraction form. First, the research questions in Table 1 were used to develop an extraction form with key elements. The data extraction form was revised and improved after numerous pilot extractions were carried out and additional articles were read. Table 5 displays the completed data extraction form. This form comprises generic metadata, such as publication year and title, as well as the 10 data extraction items that address the research question. The table lists the ten components of the research questions as R1–R9.

**Table 5: The Data Extraction Form**

No.	Extraction Item
1	Author
2	Title
3	Inclusion criteria Status
4	Publisher
5	Article Source
6	Type
7	Language
8	Country
9	ISSN
10	Publication Year
11	DOI
12	Index
13	Category
14	Infrastructure
15	Technology
16	Benefits
17	Consensus methods
18	Permission types
19	Future applications
20	Most known use cases
21	Smart contracts
22	Difficulties

### 3.5. Data Synthesis

On the form of extracted data, we conducted data analysis. For important terms, many articles utilize synonyms. So, we started by standardizing these words. We produced several bar charts, pie charts and heat maps using Excel. These graphs reveal information about data patterns.

## 4. RESULTS

The main statistics of the 34 selected studies are initially explained in the findings section. The outcomes for each study topic are then presented.

### 4.1. Main Statistics

Table 6 lists the 34 studies generated after criteria selection and quality queries. These 34 studies answer at least three research questions.

**Table 6: The 34 Studies used in This Systematic Literature Review**

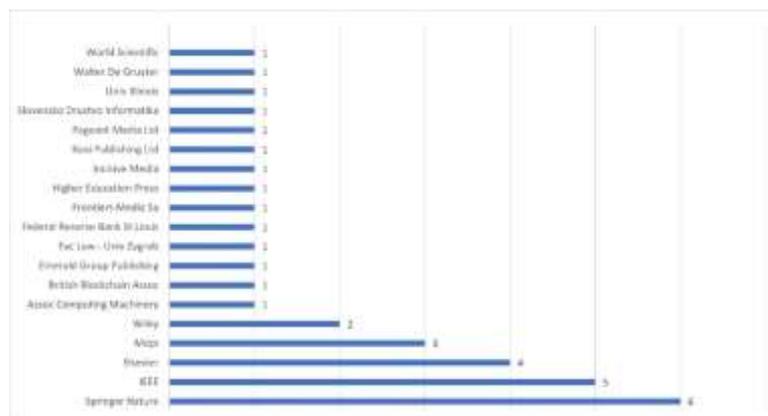
ID	Title	Year	Reference
18	Blockchain distributed ledger technology: An introduction and focus on smart contracts	2020	Hamilton, M., (2020)
19	Finance infrastructure through blockchain-based tokenization	2020	Tian, Y., Lu, Z., Adriaens, P., Minchin, R. E., Caithness, A., & Woo, J., (2020)
20	Decentralized Finance: On Blockchain- and Smart Contract-Based Financial Markets	2021	Schär, F., (2021)
21	Dizar: An Architecture of Distributed Public Key Infrastructure Based on Permissioned Blockchain	2020	Dai, Q., Xu, K., Dai, L., & Guo, S., (2020)
22	Distributed ledger technology in payments, clearing and settlement	2017	Mills, D., Wang, K., Malone, B. P., Ravi, A., Marquardt, J. C., Chen, C., ... & Baird, M., (2017)
23	DeFi-ning DeFi: Challenges & Pathway	2021	Amler, H., Eckey, L., Faust, S., Kaiser, M., Sandner, P., & Schlosser, B., (2021)
24	On the Blockchain-based General-Purpose Public Key Infrastructure	2019	Osmov, V., Kurbanniyazov, A., Hussain, R., Oracevic, A., Kazmi, S. M. A., & Hussain, F., (2019)
25	Proof of Concept of Blockchain Integration in P2P Lending for Developing Countries	2020	Mbodji, F. N., Mendy, G., Mbacke, A. B., & Ouya, S., (2020)
26	The distributed liability of distributed ledgers: Legal risks of blockchain	2018	Zetsche, D. A., Buckley, R. P., & Arner, D. W., (2018)
27	Scaling up sustainable investment through blockchain-based project bonds	2022	Chen, Y., & Volz, U., (2022)
28	Blockchain Platforms in Energy Markets-A Critical Assessment	2022	Burger, C., & Weinmann, J., (2022)
29	Evaluation of Post-Quantum Distributed Ledger Cryptography	2019	Campbell Sr., R., (2019)
30	An Architecture for Blockchain-Based Cloud Banking	2021	Do, T., (2021)
31	A blockchain and IoT-based lightweight framework for enabling information transparency in supply chain finance	2022	Guo, L., Chen, J., Li, S., Li, Y., & Lu, J., (2022)
32	Blockchain-Based Implementation of Smart Contract and Risk Management for Interest Rate Swap	2020	Ding, X., & Zhu, H., (2020)
33	Survey on Blockchain and Deep Learning	2020	Zhang, Y., Liu, Y., & Chen, C.-H., (2020)
34	An Efficient Supply Chain Architecture Based on Blockchain for High-value Commodities	2019	Xu, Z., Jiao, T., Wang, Q., Van, C. B., Wen, S., & Xiang, Y., (2019)
35	Blockchain: A Tale of Two Applications	2018	Ferreira, M., Rodrigues, S., Reis, C. I., & Maximiano, M., (2018)
36	Blockchain technology design in accounting: Game changer to tackle fraud or technological fairy tale?	2021	Centobelli, P., Cerchione, R., Vecchio, P. D., Oropallo, E., & Secundo, G., (2021)
37	Possibilities for Applying Blockchain Technology - a Survey	2021	Mijoska, M., & Ristevski, B., (2021)
38	Blockchain Applications for Industry 4.0 and Industrial IoT: A Review	2019	Alladi, T., Chamola, V., Parizi, R. M., & Choo, K.-K. R., (2019)
39	Application of analytical-network-process (ANP) for evaluation of key-performance-indicators (KPI) for application of blockchain technology in infrastructure projects	2022	Raval, P., Sarkar, D., & Devani, D., (2022)

40	Unchaining Collective Intelligence for Science, Research, and Technology Development by Blockchain-Boosted Community Participation	2021	Ducrée, J., Etzrodt, M., Bartling, S., Walshe, R., Harrington, T., Wittek, N., ... & Kogias, D., (2021)
41	Blockchains and the crypto city	2017	Potts, J., Rennie, E., & Goldenfein, J., (2017)
42	Know-Your-Customer (KYC) Requirements for Initial Coin Offerings Toward Designing a Compliant-by-Design KYC-System Based on Blockchain Technology	2021	Ostern, N. K., & Riedel, J., (2021)
43	An Overview of Regulatory Strategies on Crypto-Asset Regulation-Challenges for Financial Regulators in the Western Balkans	2020	Jovanić, T., (2020)
44	Cryptocurrencies in finance: Review and applications	2019	Flori, A., (2019)
45	A Blockchain-Based P2P Transaction Method and Sensitive Data Encoding for E-Commerce Transactions	2020	Su, X., Liu, Y., & Choi, C., (2020)
46	Eu search for regulatory answers to crypto assets and their place in the financial markets' infrastructure	2021	Ferreira, A., & Sandner, P., (2021)
47	Cryptocurrency and Blockchains: Retail to Institutional	2019	Low, R., & Marsh, T., (2019)
48	Open-Source Operational Risk: Should Public Blockchains Serve as Financial Market Infrastructures?	2018	Walch, A., (2018)
49	How should we understand the digital economy in Asia? Critical assessment and research agenda	2020	Li, K., Kim, D. J., Lang, K. R., Kauffman, R. J., & Naldi, M., (2020)
50	A Mixed Review of Cash Flow Modeling Potential of Potential of Blockchain for Modular Construction	2022	Assaf, M., Hussein, M., Alsulami, B. T., & Zayed, T., (2022)
51	Technology-enabled financing of sustainable infrastructure: A case for blockchains and decentralized oracle networks	2023	Chung, K. H. Y., Li, D., & Adriaens, P., (2023)

Figure 2 shows the distribution of studies according to the research database in a bar diagram. There are 6 of them Springer Nature, 5 of them IEEE, 4 of them Elsevier, 3 of them Mdpi, 2 of them Wiley and other publishers. Of the studies included in SLR, 21 are articles, 9 are proceeding papers, 4 are review articles and 1 is a book chapter. The study by Walch, A., (2018) is published as both an article and a book chapter.

Figure 3 shows the categories of papers included in the SLR. Many studies appear in journals related to computer science and its sub-branches. In addition, there are also journals whose categories are business, finance and economy. Apart from these, there are also a few journals that approach finance indirectly, such as law, construction building technology and urban planning.

**Figure 2: Bar Diagram of the Distribution of Publishers**



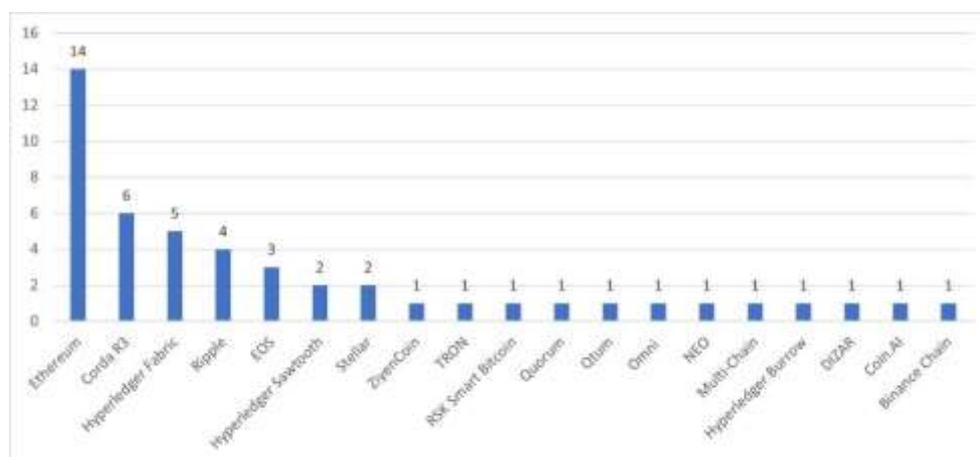


#### 4.2. RQ1: Which Blockchain Infrastructures are Used in Finance?

Blockchain technology became known with bitcoin. However, bitcoin did not offer a programmable infrastructure. In 2013, Vitalik Buterin, the inventor of Ethereum (Ethereum, 2023), introduced the idea of a programmable blockchain. Ethereum is both a programmable infrastructure and a coin. Since then, different programmable blockchain infrastructures have emerged. Hyperledger Fabric (Hyperledger community, 2023), Corda (Hearn, M., & G. B. Mike, R., 2019) and Ripple (Chase, B., & MacBrough, E., 2018) are the most well-known. Hyperledger Fabric is a permissioned blockchain infrastructure created by the Linux Foundation and can be used for different business areas. Corda and Ripple are blockchain infrastructures specialized for use in finance. Corda is a permissioned infrastructure created by R3 Company and is not associated with a crypto coin. Ripple is both a coin and a permissioned blockchain infrastructure developed by the XRPL Foundation. In addition to these blockchain infrastructures, there are many others such as Nem, Stellar, Eos, Tron and Neo.

Figure 6 shows the count of blockchain infrastructures used in the field of finance. In the SLR study, it is seen that Ethereum infrastructure is mostly used in finance. Ethereum is followed by Hyperledger Fabric and Corda. Corda is created for the sole purpose of developing blockchain applications in finance. These blockchain infrastructures are followed by Ripple, Eos, Hyperledger Sawtooth and Stellar. One of each of the other blockchain infrastructures is seen in the study.

**Figure 6: Blockchain Infrastructures Used in Finance**



While existing blockchain infrastructures are generally used, specialized blockchain infrastructures such as Dizar (21) are also used. Among the infrastructures for the use of blockchain in finance, Ethereum is seen in 14 studies (20, 23, 26, 28, 34, 35, 38, 40, 41, 42, 45, 47, 48, 49), Corda R3 in 6 (18, 26, 30, 32, 37, 48), Hyperledger Fabric in 5 (18, 24, 29, 36, 37, 48), Ripple in 4 (26, 30, 44, 47), Eos in 3 (20, 23, 42), Hyperledger Sawtooth in 2 (24, 29), Stellar in 2 (20, 30) and different blockchain infrastructures in others.

#### 4.3. RQ2: What Technologies are Used in Finance with Blockchain?

The uses of technology cover a wide range of fields. Technology is used in many different industries, including business, the health sector, finance, education, transportation, the entertainment industry and communication. In these fields, technology can boost output, present innovative goods and services and simplify people's lives.

Blockchain can often be used with different technologies. In the SLR study, Blockchain is also called as distributed ledger technology due to its distributed structure. That's why, blockchain is often mentioned together with distributed ledger technology. As seen in Figure 7, the "Distributed Ledger" is expressed 20 times (22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 33, 37, 40, 41, 43, 44, 46, 47, 48, 51), the "Financial" 3 times (44, 46, 47), the "Building information modeling" 2 times (39, 50), the "Government" 2 times (41, 43), the "Internet" 2 times (29, 45) and other technologies is seen one time each.

Figure 7: Technologies Used with Blockchain in Finance

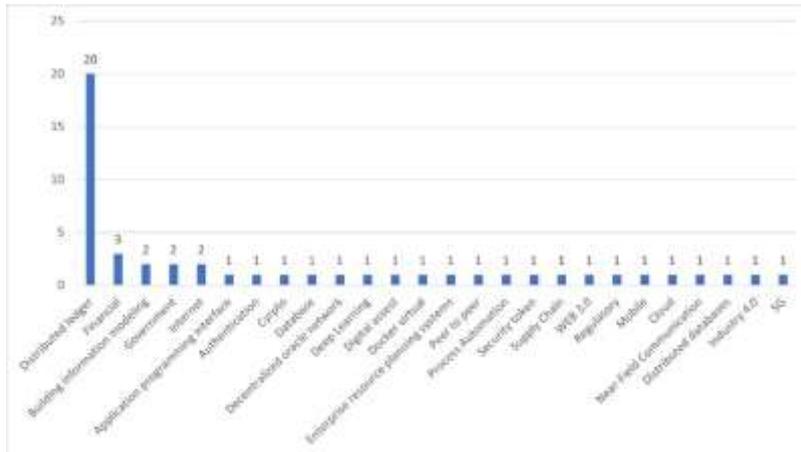
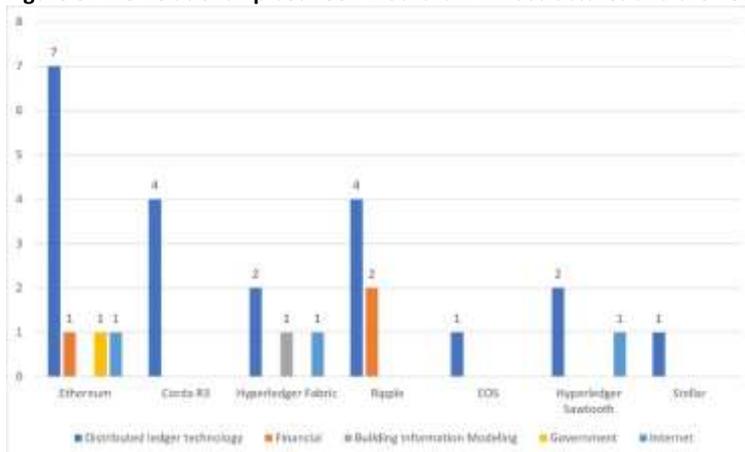


Figure 8 shows the relationship between blockchain infrastructures and the technologies used with blockchain. Due to the distributed structure of the blockchain, distributed ledger technology is included in all infrastructures. In addition to distributed ledger technology, “Financial”, “Government” and “Internet” technology are also used with Ethereum infrastructure. While Corda is only used with “Distributed ledger” technology, the use of Ripple with financial technologies is remarkable.

Figure 8: The Relationship between Blockchain Infrastructures and the Technology Used with Blockchain



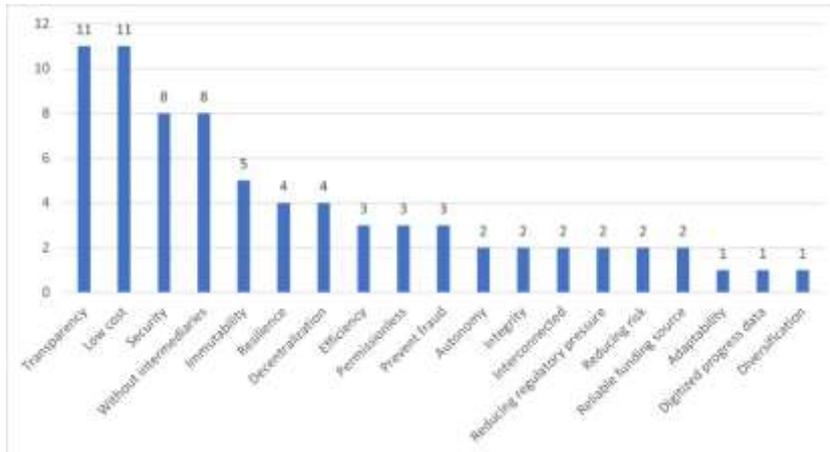
4.4. RQ3: What are the Benefits of Implementing Blockchain in Finance?

Blockchain is a system that enables real-time, immutable digital asset transactions without the need for a reliable third party. The financial sector benefits from blockchain in numerous ways, including increased transparency and confidence, decreased costs and simplified operations.

The SLR study contains different expressions for the benefits of blockchain in finance. We grouped these expressions and reduced them to 19. For example, we singularized expressions such as "improving network resiliency", "durability" and "improved fault-tolerance" as "Resilience". We performed this process for all expressions.

As seen in Figure 9, the “Transparency” expression is included in 11 papers (22, 23, 24, 25, 27, 37, 46, 47, 48, 49, 51), the “Low cost” expression in 11 papers (26, 28, 30, 32, 42, 45, 46, 47, 49, 50, 51), the “Security” expression in 8 papers (24, 25, 32, 34, 36, 38, 47, 49), the “Without intermediaries” in 8 papers (18, 20, 22, 23, 26, 40, 42, 48), the “Immutability” in 5 papers (18, 24, 37, 40, 48), the “Resilience” in 4 papers (22, 24, 41, 48), the “Decentralization” in 4 papers (23, 24, 37, 40), the “Efficiency” in 3 papers (26, 46, 51), the “Permissionless” in 3 papers (23, 37, 41), the “Prevent fraud” in 3 papers (24, 30, 36), the “Autonomy” in 2 papers (23, 37), the “Integrity” in 2 papers (24, 40), the “Interconnected” in 2 papers (23, 31), the “Reducing regulatory pressure” in 2 papers (20, 43), the “Reducing risk” in 2 papers (22, 32), the “Reliable funding source” in 2 papers (19, 39) and the others once in the papers.

Figure 9: Benefits of Implementing Blockchain in Finance



4.5. RQ4: Which Consensus Methods of Blockchain are Used in Finance?

The process by which a network of distributed nodes or participants agree on the validity of transactions and the state of the blockchain ledger is referred to as consensus in the context of blockchain technology. Consensus is essential for guaranteeing that all participants have a consistent and unchangeable record of transactions. There would be no trust in the blockchain network if there is no consensus.

Blockchain infrastructures have their own consensus methods. For example, Ethereum uses the Proof of Work consensus method, while Hyperledger Fabric uses the Byzantine Fault Tolerance consensus method.

As seen in Figure 10, the "Proof of Work" expression is included in 7 papers (18, 21, 26, 36, 40, 45, 47), the "Practical Byzantine Fault Tolerance" in 3 papers. (25, 31, 37), the "Proof of Stake" in 3 papers (28, 43, 47), the "Proof of Authority" in 2 papers (34, 38) and the other consensus methods once in the papers.

Consensus methods are directly related to the blockchain infrastructure. For example, while ethereum used Proof of Work before 2022, it switched to Proof of Stake consensus method for energy efficiency, security and validation reasons. As mentioned above, blockchain infrastructures can change consensus methods. As seen in Figure 11, the "Proof of work" consensus method is valid in all blockchain infrastructures in the field of finance. The "Practical Byzantine Fault Tolerance" method is available in Hyper ledger Fabric and Corda R3, the "Proof of Stake" method is available in Ethereum and Ripple, the "Proof of Authority" method is only available in the paper related to Ethereum.

Figure 10: Consensus Methods of Blockchain in Finance

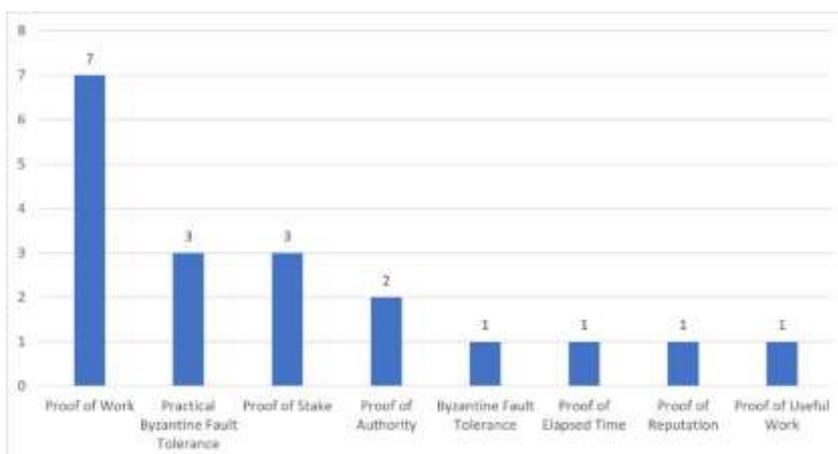
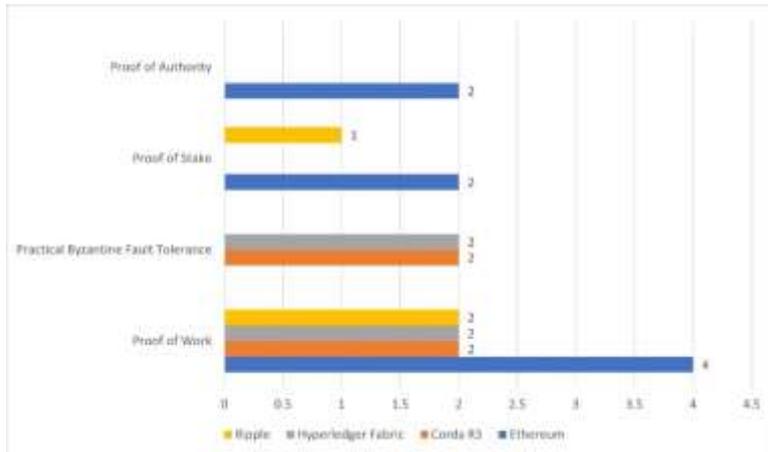


Figure 11: The Relationship between Blockchain Infrastructures and Consensus Methods



4.6. RQ5: What Permission Types of Blockchain are Used in Finance?

There are four types of blockchain that are widely accepted. These networks are public blockchain networks, private blockchain networks, hybrid blockchain networks and consortium blockchain networks (Karadag, B., Akbulut, A., & Zaim, A. H., 2022). They can be permissioned or permissionless depending on their type and blockchain infrastructures support different types of permission. For example, Ethereum supports the permissionless, while Corda and Hyperledger Fabric provide the Permissioned type. Some blockchain infrastructures have both permissioned and permissionless types. Permission type is an important issue when developing blockchain-based applications in finance and permissioned type is generally preferred.

Figure 12: Permission Types of Blockchain in Finance

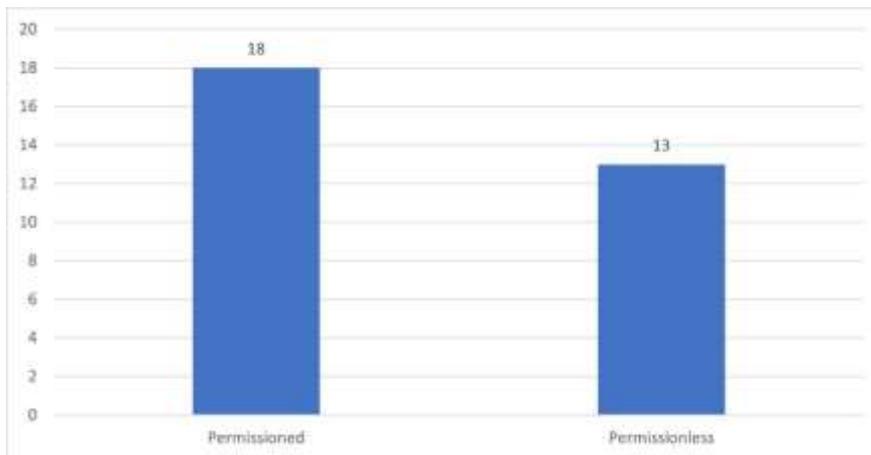
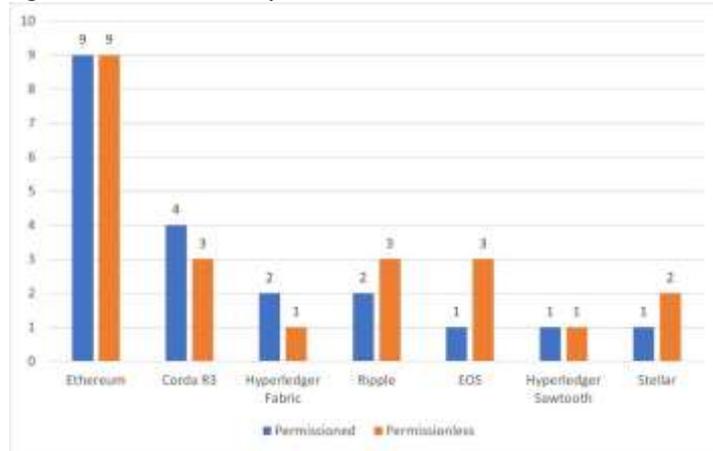


Figure 13: The Relationship between Blockchain Infrastructures and Permission Types



As seen in Figure 12, among the permission types for the use of blockchain in finance, the “Permissioned” is seen in 18 studies (18, 19, 20, 21, 22, 24, 25, 26, 28, 31, 32, 36, 38, 40, 41, 45, 47, 48), and the “Permissionless” in 13 studies (20, 23, 24, 26, 30, 34, 36, 40, 42, 45, 46, 47, 48) in the papers. Some blockchain infrastructures provide either permissioned or permissionless functions, while others provide both. As seen in Figure 13, both permission types are at an equal in the papers where Ethereum infrastructure is included. In the SLR study, the number of permissioned is higher in Hyperledger Fabric and Corda R3, while the number of permissionless is higher in Ripple, EOS and Stellar. In Hyperledger Sawtooth, both are equal.

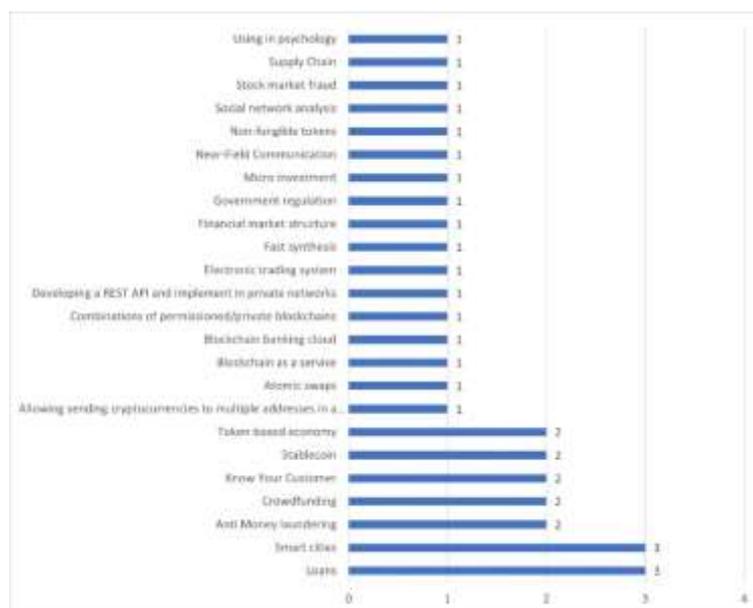
**4.7. RQ6: What are the Potential Future Applications of Blockchain Technology in Finance?**

Blockchain became a key subject after Bitcoin entered our lives. However, Bitcoin did not provide a programmable blockchain solution. Ethereum, founded in 2013 by Vitalik Buterin, provided both a crypto asset and a programmable blockchain technology. Since then, some apps utilizing blockchain technology have been developed. Although some blockchain-based applications have been made in the field of finance (56), they have not become widespread at the desired level.

Although we currently see a small number of blockchain applications, it has great potential for the future thanks to its transparency, security and without intermediaries.

Potential future applications of blockchain technology in finance is seen Figure 14. Among these, the “Loans” is mentioned 3 times (20, 34, 50), the “Smart cities” 3 times (19, 41, 51), the “Anti money laundering” 2 times (26, 43), the “Crowdfunding” 2 times (20, 40), the “Know your customer” 2 times (26, 23), the “Stablecoin” 2 times (20, 44), the “Token-based economy” 2 times (46, 49) and the other future applications once in the papers.

Figure 14: Potential Future Applications of Blockchain in Finance

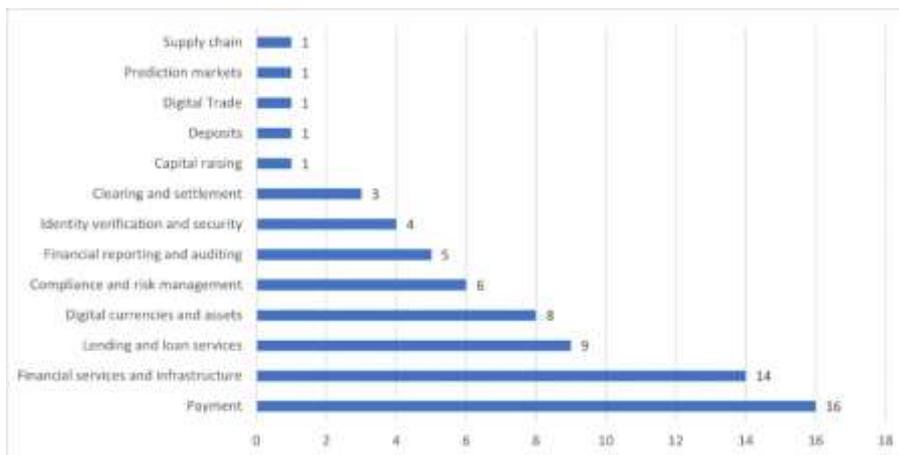


**4.8. RQ7: What are the Most Common Uses of Blockchain Technology in the Financial Industry?**

Nearly a hundred answers are obtained for this question. These answers are then reduced to 13 different groups. For example, expressions such as "Digital currencies", "Digital asset exchange", "Tokenization process", "Digital rights to ownership" are grouped as "Digital currencies and assets". Similarly, expressions such as "Authentication", "Digital signature algorithm", "Identity verification", "Verification", "Identification", "Digital identity" are grouped as "Identity verification and security". This grouping process took place for eight groups.

As seen in Figure 15, expressions belonging to the group "Payment" in 16 papers (18, 22, 23, 26, 27, 28, 29, 30, 34, 37, 41, 43, 46, 47, 50, 51), the "Financial services and infrastructure" are mentioned in 14 papers (23, 27, 28, 30, 35, 37, 44, 45, 46, 47, 48, 49, 50, 51), the "Lending and loan services" in 9 papers (18, 20, 23, 25, 26, 27, 30, 38, 45), the "Digital currencies and assets" in 8 papers (18, 19, 27, 30, 37, 40, 42, 46), the "Compliance and risk management" in 6 papers (31, 32, 33, 40, 42, 43), the "Financial reporting and auditing" in 5 papers (24, 29, 30, 34, 37), the "Identity verification and security" in 4 papers (18, 30, 36, 37), the "Clearing and settlement" in 3 papers (22, 26, 30) and other non-group expressions once in the papers.

**Figure 15: Most Common Uses of Blockchain in Finance**

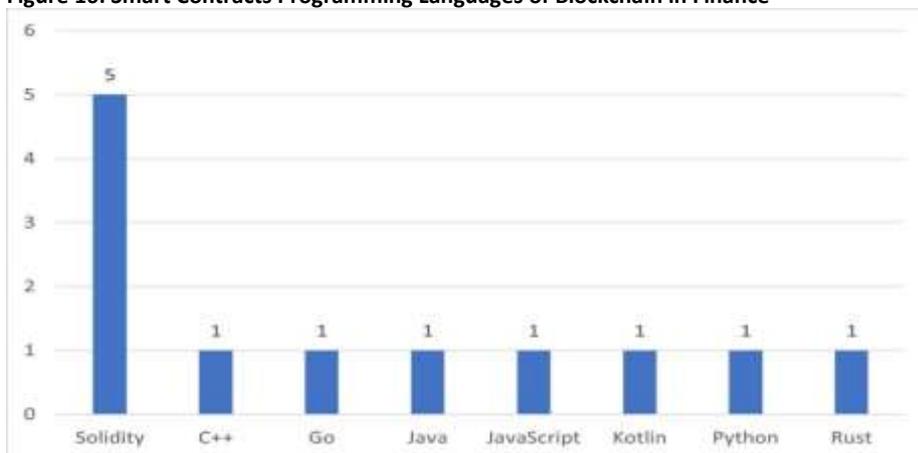


**4.9. RQ8: Which Smart Contracts Programming Languages of Blockchain are Used in Finance?**

Although the idea of smart contracts is not new, Ethereum is the first to apply them in the field of blockchain technology. Solidity, a programming language, is used to create smart contracts on Ethereum. A variety of smart contract software languages are available on other blockchain infrastructures that came into existence after Ethereum. Kotlin in Corda, Go, Node.js, Java in Hyperledger Fabric, JavaScript, Java, Go in Stellar, and JavaScript, Java, Python in Ripple are a few examples of programming languages that can be used to build smart contracts.

As seen in Figure 16, among the smart contracts programming languages of blockchain in finance, the "Solidity" appears in 5 papers (18, 19, 34, 35, 45) and the other programming languages (C++, Go, Java, JavaScript, Kotlin, Python, Rust) once in the papers.

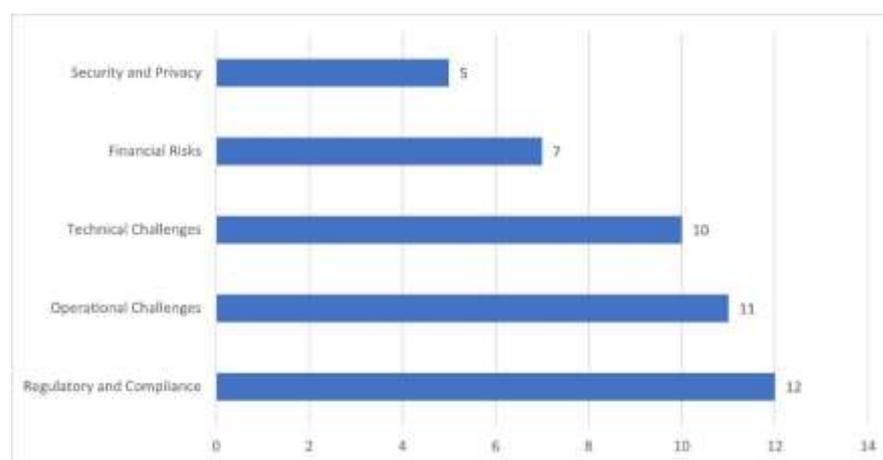
**Figure 16: Smart Contracts Programming Languages of Blockchain in Finance**



#### 4.10. RQ9: What are the Challenges of Implementing Blockchain in Finance?

The implementation of blockchain in finance has some challenges. Especially on the side of regulated institutions such as banks and insurance companies, difficulties are more common. In this SLR study, 45 different challenge expressions are identified in the papers. Then, these difficulty expressions are categorized into 5 groups. For example, expressions such as "Computing power", "Energy consumption", "Scalability of block data", "Run smart contracts" are grouped as "Technical Challenges". Similarly, expressions such as "Legal", "Open source", "Regulatory", "Settlement", "Oracles" are grouped as "Regulatory and Compliance".

**Figure 17: Challenges of Implementing Blockchain in Finance**



As seen in Figure 17, expressions belonging to the group "Regulatory and Compliance" in 12 papers (22, 23, 28, 30, 31, 37, 38, 39, 41, 46, 48, 49), the "Operational Challenges" in 11 papers (19, 20, 21, 22, 28, 36, 37, 39, 47, 50, 51), the "Technical Challenges" in 10 papers (18, 20, 23, 25, 29, 36, 38, 40, 47, 48), the "Financial Risks" in 7 papers (22, 23, 26, 27, 32, 40, 43) and the "Security and Privacy" in 5 papers (19, 23, 25, 26, 38) are included.

## 5. DISCUSSION

The most comprehensive systematic literature review on blockchain technology in the field of finance is presented in this paper. Nine questions were evaluated as research questions, covering both the technology of blockchain and its benefits and challenges. Technical questions were not adequately answered at the necessary level. However, the responses to the questions about benefits and challenges were quite good. The answers to the research questions varied widely as technical aspects such as blockchain infrastructure, consensus method, permission type, smart contract programming language, etc., varied. However, the answers to the questions on benefits, challenges, use cases, and potential future applications were similar. Blockchain cannot be used at the desired level in the financial sector due to issues like regulation and compliance. This is why the majority of studies are still theoretical. If the regulatory issues are resolved, systematic literature review studies can be conducted more effectively in the future with the use of blockchain technology.

While blockchain technology is generally closely related to the field of finance, there are not enough articles and real-life applications available. Therefore, based on the search results, 52 articles were identified. After conducting a quality assessment and applying selection criteria, this number was reduced to 34 articles. Due to the fact that Ethereum is older than other infrastructures, the number of statistics of Ethereum stands out. Although some studies on infrastructures such as Hyper Ledger, Corda R3, Ripple and Stellar are available, other blockchain infrastructures are not available in academic publications.

## 6. CONCLUSION AND FUTURE WORK

This study is a systematic literature review (SLR) on the use of Blockchain technology in finance. In the study, 52 articles were evaluated, and 34 articles were included in the study after quality and evaluation checks. We asked 9 research questions to these articles and tried to find answers. The questions were generally in three categories. The first type of questions tried to find technical answers. For example, which Blockchain infrastructure is used, which technology is used with blockchain technology, which permission and consensus method is applied. The second category of questions tried to find the benefits and challenges. The most satisfactory answers came from these research questions. Almost all articles included expressions showing the benefits and challenges of blockchain. Questions in the third category were related to current and future application areas. We tried to find answers to the use cases of blockchain in finance and potential use cases in the future.

The answers to these questions were also satisfactory. Thanks to the study, it is predicted that it is applied in different areas and potentially its use will become widespread in the future.

The study's findings will clear the way for individuals who choose to pursue this field of study. There has never been an SLR study that examined blockchain's use in finance. In-depth information about the sectoral sectors that can apply blockchain technology is provided in this study, along with its infrastructures, benefits and challenges. This initiative is for those who plan to work on this topic.

Future SLR studies can be carried out for several industries. In addition to finance, a similar study might also be conducted in other fields, such as insurance, supply chains, government relations, and health. Additionally, with the growth of blockchain in the financial sector, a more in-depth study can be conducted in the near future.

## REFERENCES

- Ali, M. S., Babar, M. A., Chen, L., & Stol, K.-J. (2010). A systematic review of comparative evidence of aspect-oriented programming. *Information and Software Technology*, 52(9), 871–887.
- Alladi, T., Chamola, V., Parizi, R. M., & Choo, K.-K. R. (2019). Blockchain applications for industry 4.0 and industrial IoT: A review. *IEEE Access*, 7, 176935–176951.
- Amler, H., Eckey, L., Faust, S., Kaiser, M., Sandner, P., & Schlosser, B. (2021). Defi-ning defi: Challenges & pathway. In *2021 3rd Conference on Blockchain Research & Applications for Innovative Networks and Services (BRAINS)* (pp. 181–184).
- Amsyar, I., Christopher, E., Dithi, A., Khan, A. N., & Maulana, S. (2020). The challenge of cryptocurrency in the era of the digital revolution: A review of systematic literature. *Aptisi Transactions on Technopreneurship (ATT)*, 2(2), 153–159.
- Assaf, M., Hussein, M., Alsulami, B. T., & Zayed, T. (2022). A mixed review of cash flow modeling: Potential of blockchain for modular construction. *Buildings*, 12(12).
- Böhme, R., Christin, N., Edelman, B., & Moore, T. (2015). Bitcoin: Economics, technology, and governance. *Journal of Economic Perspectives*, 29(2), 213–238.
- Burger, C., & Weinmann, J. (2022). Blockchain platforms in energy market; a critical assessment. *Journal of Risk and Financial Management*, 15(11).
- Campbell Sr., R. (2019). Evaluation of post-quantum distributed ledger cryptography. *The Journal of The British Blockchain Association*, 2(1), 321.
- Centobelli, P., Cerchione, R., Vecchio, P. D., Oropallo, E., & Secundo, G. (2021). Blockchain technology design in accounting: Game changer to tackle fraud or technological fairy tale? *Accounting, Auditing & Accountability Journal*, 35(7), 1566–1597.
- Chang, S. E., Luo, H. L., & Chen, Y. (2020). Blockchain-enabled trade finance innovation: A potential paradigm shift on using letter of credit. *Sustainability*, 12(1), 15–28.
- Chase, B., & MacBrough, E. (2018). Analysis of the XRP ledger consensus protocol. *CoRR abs/1802.07242*. arXiv preprint arXiv:1802.07242.
- Chen, Y., & Volz, U. (2022). Scaling up sustainable investment through blockchain-based project bonds. *Development Policy Review*, 40(3), e12582.
- Chowdhury, M. U., Suchana, K., Alam, S. M. E., & Khan, M. M. (2021). Blockchain application in banking system. *Journal of Software Engineering and Applications*, 14(1), 298–311.
- Chung, K. H. Y., Li, D., & Adriaens, P. (2023). Technology-enabled financing of sustainable infrastructure: A case for blockchains and decentralized oracle networks. *Technological Forecasting and Social Change*, 187, 122258.
- Dai, Q., Xu, K., Dai, L., & Guo, S. (2020). Dizar: An architecture of distributed public key infrastructure based on permissioned blockchain. In *Blockchain Technology and Application* (pp. 156–186). Singapore: Springer.
- Ding, X., & Zhu, H. (2020). Blockchain-based implementation of smart contract and risk management for interest rate swap. In *Blockchain Technology and Application* (pp. 210–219). Singapore: Springer.
- Do, T. (2021). An architecture for blockchain-based cloud banking. In *IACR Cryptology ePrint Archive*.
- Ducrée, J., Etzrodt, M., Bartling, S., Walshe, R., Harrington, T., Wittek, N., ... & Kogias, D. (2021). Unchaining collective intelligence for science, research, and technology development by blockchain-boosted community participation. *Frontiers in Blockchain*, 4.
- Ethereum. (2023). Ethereum whitepaper.
- Ferreira, A., & Sandner, P. (2021). EU search for regulatory answers to crypto assets and their place in the financial markets' infrastructure. *Computer Law & Security Review*, 43, 105632.
- Ferreira, M., Rodrigues, S., Reis, C. I., & Maximiano, M. (2018). Blockchain: A tale of two applications. *Applied Sciences*, 8(9), 304–321.
- Flori, A. (2019). Cryptocurrencies in finance: Review and applications. *International Journal of Theoretical and Applied Finance*, 22(05), 1950020.

- Garg, P., Gupta, B., Chauhan, A. K., Sivarajah, U., Gupta, S., & Modgil, S. (2021). Measuring the perceived benefits of implementing blockchain technology in the banking sector. *Technological Forecasting and Social Change*, 163, 120407.
- Gatteschi, V., Lamberti, F., Demartini, C., Pranteda, C., & Santamaria, V. (2018). Blockchain and smart contracts for insurance: Is the technology mature enough? *Future Internet*, 10(2), 89-101.
- Grima, S., Spiteri, J., & Romanova, I. (2020). A steep framework analysis of the key factors impacting the use of blockchain technology in the insurance industry. *Geneva Papers on Risk and Insurance - Issues and Practice*, 45, 398–425.
- Guo, L., Chen, J., Li, S., Li, Y., & Lu, J. (2022). A blockchain and IoT-based lightweight framework for enabling information transparency in supply chain finance. *Digital Communications and Networks*, 8(4), 576–587.
- Gurbuz, H. G., & Tekinerdogan, B. (2018). Model-based testing for software safety: a systematic mapping study. *Software Quality Journal*, 26, 1327–1372.
- Hamilton, M. (2020). Blockchain distributed ledger technology: An introduction and focus on smart contracts. *Journal of Corporate Accounting & Finance*, 31(2), 7–12.
- Javaid, M., Haleem, A., Singh, R. P., Suman, R., & Khan, S. (2022). A review of blockchain technology applications for financial services. *Bench Council Transactions on Benchmarks, Standards and Evaluations*, 2(3), 100073.
- Jovanic, T. (2020). An overview of regulatory strategies on crypto-asset regulation-challenges for financial regulators in the Western Balkans. In *EU Financial Regulation and Markets-Beyond Fragmentation and Differentiation*. Zagreb: Conference Proceedings.
- Karadağ, B., Akbulut, A., & Zaim, A. H. (2022). A review on blockchain applications in fintech ecosystem. In *2022 International Conference on Advanced Creative Networks and Intelligent Systems (ICACNIS)* (pp. 1–5).
- Kitchenham, B., & Charters, S. (2007). Guidelines for performing systematic literature reviews in software engineering.
- Kshetri, N. (2018). Blockchain's roles in meeting key supply chain management objectives. *International Journal of Information Management*, 39, 80-89.
- Li, K., Kim, D. J., Lang, K. R., Kauffman, R. J., & Naldi, M. (2020). How should we understand the digital economy in Asia? critical assessment and research agenda. *Electronic Commerce Research and Applications*, 44, 101004.
- Low, R., & Marsh, T. (2019). Cryptocurrency and blockchains: Retail to institutional. *Journal of Investing*, 29(1), 18–30.
- Mainelli, M., & Milne, A. (2016). The impact and potential of blockchain on the securities transaction lifecycle. SWIFT Institute Working (2015-007). London: SWIFT Institute.
- Mbodji, F. N., Mendy, G., Mbacke, A. B., & Ouya, S. (2020). Proof of concept of blockchain integration in p2p lending for developing countries. In *E-Infrastructure and e-Services for Developing Countries* (pp. 59–70). Cham: Springer.
- Mijoska, M., & Risteovski, B. (2021). Possibilities for applying blockchain technology—a survey. *Informatica*, 45(3), 319–333.
- Mills, D., Wang, K., Malone, B. P., Ravi, A., Marquardt, J. C., Chen, C., ... & Baird, M. (2017). Distributed ledger technology in payments, clearing and settlement. *The Journal of Financial Market Infrastructures*, 6(8), 207–249.
- Osmov, V., Kurbanniyazov, A., Hussain, R., Oracevic, A., Kazmi, S. M. A., & Hussain, F. (2019). On the blockchain-based general-purpose public key infrastructure. In *2019 IEEE/ACS 16th International Conference on Computer Systems and Applications (AICCSA)* (pp. 1–8).
- Ostern, N. K., & Riedel, J. (2021). Know-your-customer (kyc) requirements for initial coin offerings. *Business & Information Systems Engineering*, 63(5), 551–567.
- Panait, A.-E., Olimid, R. F., & Stefanescu, A. (2020). Identity management on blockchain—privacy and security aspects. arXiv preprint arXiv:2004.13107.
- Potts, J., Rennie, E., & Goldenfein, J. (2017). Blockchains and the crypto city. *It-Information Technology*, 59(6), 285–293.
- Raval, P., Sarkar, D., & Devani, D. (2022). Application of analytical-network-process (anp) for evaluation of key-performance-indicators (kpi) for application of blockchain technology in infrastructure projects. *Innovative Infrastructure Solutions*, 7.
- Schär, F. (2021). Decentralized Finance: On Blockchain- and Smart Contract-Based Financial Markets. *Review*, 103(2), 153–174.
- Su, X., Liu, Y., & Choi, C. (2020). A blockchain-based p2p transaction method and sensitive data encoding for e-commerce transactions. *IEEE Consumer Electronics Magazine*, 9(4), 56–66.
- Tian, Y., Lu, Z., Adriaens, P., Minchin, R. E., Caithness, A., & Woo, J. (2020). Finance infrastructure through blockchain-based tokenization. *Frontiers of Engineering Management*, 7(4), 485–499.
- Wardhani, D. K., Sawarjuwono, T., & Budisusetyo, S. (2018). Blockchain in capital markets: A revolution of the trading system in stock exchange. *The Indonesian Accounting Review*, 12(1), 35-49.
- Walch, A. (2018). Chapter 11 - open-source operational risk: Should public blockchains serve as financial market infrastructures? In *Handbook of Blockchain, Digital Finance, and Inclusion, Volume 2* (pp. 243–269). Academic Press.

Xu, Z., Jiao, T., Wang, Q., Van, C. B., Wen, S., & Xiang, Y. (2019). An efficient supply chain architecture based on blockchain for high-value commodities. In Proceedings of the 2019 ACM International Symposium on Blockchain and Secure Critical Infrastructure (pp. 81–88).

Zhang, Y., Liu, Y., & Chen, C.-H. (2020). Survey on blockchain and deep learning. In 2020 IEEE 19th International Conference on Trust, Security and Privacy in Computing and Communications (TrustCom) (pp. 1989–1994).

Zetsche, D. A., Buckley, R. P., & Arner, D. W. (2018). The distributed liability of distributed ledgers: Legal risks of blockchain. *University of Illinois Law Review*, 1361.